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SECTION II.7B

Operational Area Monitoring Plan for the Long-Term Hydrological Monitoring Program Off The Nevada Test Site

by

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FOREWORD

This is one of a series of Operational Area Monitoring Plans that comprise the overall Environmental Monitoring Plan for the DOE Field Office, Nevada (DOE/NV) nuclear and non-nuclear testing activities associated with the Nevada Test Site (NTS). These Operational Area Monitoring Plans are prepared by various DOE support contractors, NTS user organizations, and federal or state agencies supporting DOE NTS operations. These plans and the parent Environmental Monitoring Plan are a part of the DOE Environmental Protection Program required by DOE Order 5400.1 and the DOE Orders, executive orders, and state and federal regulatory requirements referenced herein.

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1.0 Introduction

The Long-Term Hydrological Monitoring Program (LTHMP) was established by DOE/NV in 1972 to determine whether, or not, radioactivity from underground nuclear explosive tests has contaminated the groundwater in the vicinity of the test sites. The locations at which the LTHMP is operative include the NTS and ten sites away from the NTS where underground tests have been conducted. The underground tests were conducted for various purposes, i.e., Plowshare tests, Vela Uniform (seismic signal modification) tests, calibrations tests, and weapons tests of various kinds.

The PLOWSHARE Program was instituted to develop peaceful uses for nuclear explosives. Some of the proposed uses were excavation (e.g., dredging harbors and digging canals), power production, crushing ore bodies, liquefying oil shale, and fracturing tight rock formations to increase natural gas flow. The purpose of the VELA UNIFORM Program was to improve understanding of the characteristics of seismic waves generated by underground nuclear explosions and improve this country's capability to detect, identify, and locate underground nuclear detonations and differentiate them from other causes of seismic events. This understanding was considered essential for verification of various treaty provisions.

The LTHMP was an outgrowth of monitoring conducted during and after test activities and during site clean-up operations. The initial monitoring was conducted by the U.S. Public Health Service (PHS), U.S. Geological Survey (USGS), and contractors including Teledyne and Eberline. The U.S. Environmental Protection Agency (EPA) assumed the duties that had been performed by PHS at the time of its creation in 1970. In 1972, the various groundwater monitoring activities at nuclear weapons testing sites were consolidated into the LTHMP and the monitoring well networks were incorporated with little or no change in network design. Most of these wells were sited and emplaced by USGS and/or contractors. To the present, USGS remains a participant in the LTHMP, primarily in the areas of well emplacement and routine sampling. Primary responsibility for day-to-day operations has been delegated by DOE/NV to the EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV). Program oversight is performed by DOE and contractors, including the Desert Research Institute (DRI).

The LTHMP for the NTS is described in Section II.7A and includes more than 50 wells and springs on and in the proximity of the NTS. The portion of the LTHMP that covers the non-NTS test sites in Nevada and other states is described in this Operational Area Monitoring Plan (OAMP). The operational areas and activities are described in the individual sections as follows:

- **Amchitka Island, Alaska** - the background locations and CANNIKIN, LONG SHOT, and MILROW tests.
- **Project RIO BLANCO** - a Plowshare test in Colorado.
- **Project RULISON** - a Plowshare test in Colorado.
- **Project DRIBBLE** - several Vela Uniform tests in Mississippi.
- **Project FAULTLESS** - a site calibration test in Nevada.

- **Project SHOAL** - a Vela Uniform test in Nevada.
- **Project GASBUGGY** - a Plowshare test in New Mexico.
- **Project GNOME** - a multipurpose test in New Mexico.

2.0 Effluents

At the present time there are no known effluents at any of the ten sites discussed below. There are indications that tritium escaped from the LONG SHOT cavity soon after detonation of that test, but the concentration of tritium in water samples has been decreasing at a rate somewhat faster than would be expected from just radioactive decay, an indication of diffusion. There is no indication from groundwater monitoring that tritium is continuing to leak from the test cavity.

At the Dribble site on the Tatum Salt Dome near Baxterville, Mississippi, disposal of drilling muds and fluids near surface ground zero resulted in tritium contamination of shallow groundwater onsite. This shallow water, between 4 and 10 feet deep, and a surficial aquifer that is 30 feet deep both consist of non-potable water, and the tritium concentration in them has decreased to less than the National Primary Drinking Water Regulations value of 20,000 pCi/L ($2 \times 10^{-5} \mu Ci/mL$. There is no indication from ground and surface water monitoring that any radioactivity is presently escaping from the test cavity. There was no detectable release from any of the other test sites.

3.0 Effluent Monitoring Plan

Since there are no known effluents from any of the 10 off-NTS test sites, there is no effluent monitoring plan for any of them. Environmental surveillance is conducted at each of the sites through a ground and surface water monitoring program as described in Section 4.0 below.

4.0 Environmental Surveillance Plan

Just prior to and for a short while after each of the tests described in the following sections, PHS, USGS, and/or contractors conducted test-support monitoring that included air, water, milk, and vegetation sampling and measurement of external gamma exposures. Additional monitoring was conducted during site clean-up activities. The LTHMP was instituted in 1972 to maintain an effective surveillance program at each site. In most cases, this monitoring program is restricted to groundwater and, in some cases, surface water sampling. Monitoring of other potential exposure pathways has been occasionally incorporated into the LTHMP as special environmental surveillance studies at the request of DOE/NV. These investigations are generally undertaken to address concerns of local residents.

4.1 Rationale for Monitoring

The primary objective of the LTHMP is to safeguard the public drinking water supply from nuclear weapons test-created radioactive contaminants. This objective is met by periodic sampling and analysis of groundwater and, in some cases, surface water in the vicinity of ground zero and in inhabited offsite areas. The monitoring rationale is based on the assumption that groundwater is the principal transporting medium, i.e., that leaks from the underground cavity created by a nuclear explosives test would be detectable in the groundwater before any indication of effluents in other media.

In addition to the primary objective, DOE/NV has acknowledged its responsibility for obtaining and for disseminating data acquired from all locations where nuclear devices have been tested. Those data must be appropriate and adequate to:

- Assure public safety.
- Inform the public, news media, and scientific community about any radiological contamination.
- Document compliance with existing federal, state, and local antipollution requirements.

4.2 Design Criteria

Design criteria must be based on achievement of the program objective(s). In the case of the LTHMP, the objective is to protect the public drinking water supply from radioactive contaminants created by nuclear weapons testing. The LTHMP, therefore, is designed to meet this objective. The design may not be adequate to address other objectives, such as characterization of aquifers, groundwater plume modeling, or monitoring of advanced hydrological parameters.

There are two important elements to consider in design criteria. One is the network design. The other is data quality. Both must be adequate to address the program objectives.

4.2.1 Network Design

Groundwater is the principle media monitored in the LTHMP because, as stated in the Rationale for Monitoring section, above, groundwater is assumed to be the principle transporting medium. Sampling wells are located in the vicinity of ground zero and in inhabited offsite areas. Wells in the offsite area are designed to monitor contamination levels at points of use by local residents, while the near GZ wells are designed to be an "early warning system" by detecting leakage of radiation in the vicinity of the test cavity.

Sampling is conducted on a fixed schedule specific to the site. Amchitka Island is sampled every two years; the remainder of the off-NTS sites are sampled annually. Wells on the NTS are sampled at either monthly or semiannual intervals. A staggered scheduled is used for the semiannually sampled wells; thus some wells are sampled in each calendar month. This sampling schedule is more than adequate to meet the program objective as it is highly doubtful that groundwater flow rates would result in gross changes in contamination levels between sampling intervals.

Tritium is the primary radionuclide of interest, although all samples are gamma scanned for the presence of other radionuclides. Tritium, an isotope of hydrogen, becomes incorporated into water molecules and, therefore, is most likely to be the first radionuclide detected in the aquifer. A modified analysis procedure is employed in the LTHMP which includes an enrichment step, resulting in a lower limit of detection than can be achieved with standard methodology. The enrichment analysis procedure permits detection of tritium activities as low as 10^{-8} µCi/mL, well below the National Primary Drinking Water Regulation (40 CFR 141) standard of 2×10^{-5} µCi/mL.[1]

To meet the primary objective of the LTHMP, samples must be representative of public drinking water supplies. At the time the wells were emplaced, it was thought that the sampled aquifers were those most likely to become contaminated should radioactivity leak from the test cavity and that the wells were representative of public point of use supplies. Additionally, wells were emplaced to meet the secondary objective of compliance with federal, state, and local antipollution laws. Advances in the science of hydrology and changes in regulations have resulted in the need to reevaluate the network design. An oversight investigation conducted as part of the evaluation process indicated that the existing network design fails to meet the required objective in some cases (Chapman and Hokett, 1991). The process of network design evaluation is continuing. Currently, a Remedial Investigation/Feasibility Study (RI/FS) is being prepared for the Project DRIBBLE site (see Section 4.6). Network designs will be modified as required by the results of the evaluation process and as permitted by funding.

4.2.2 Data Quality Objectives

The other critical element in design criteria is data quality. Data quality objectives (DQOs) describe the data quality required to meet the program objectives. These DQOs are defined in terms of detectability, precision, representativeness, comparability, completeness, and accuracy. To insure detection of contamination as soon as possible after release, the detection levels for ^3H must be low, at about environmental levels, so a ^3H enrichment methodology is used. Precision, monitored thorough use of duplicate and blind samples, must be within ± 10% (conventional radiochemical analyses) or 20% (enriched ^3H analyses) for activities greater than 10 times the minimum detectable activity [defined as the minimum detectable concentration (MDC)] and ± 60% for activities greater than the MDC but less than 10 times the MDC. Precision is not defined for activities less than the MDC. By definition, activities less than the MDC cannot be distinguished from background at the 95% confidence interval.

Representativeness is defined as "the degree to which the data accurately and precisely represent a characteristic of a parameter, variation of a property, a process characteristic, or an operation condition" (Stanley and Verner, 1985). To meet the objective of the LTHMP to detect contamination of public drinking water supplies by manmade radionuclides, samples should be collected from known depths, representing aquifers with the greatest potential to become contaminated and sampling locations should be concentrated in the direction downgradient from the nuclear test cavity. A recent oversight investigation has indicated that samples may not meet the representativeness objective at all sites (Chapman and Hokett, 1991). An evaluation process is ongoing, with the objective of improving sample representativeness.

Comparability is defined as "the confidence with which one data set can be compared to another" (Stanley and Verner, 1985). Comparability of data are assured by use of standard

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[1] The National Primary Drinking Water Regulation states that the sum of all beta/gamma emitter concentrations in drinking water cannot lead to an exposure exceeding 4 mrem/year, assuming a person were to drink two liters per day for a year (40 CFR 141). Assuming tritium to be the only radioactive contaminant yields the activity concentration stated.

operating procedures (SOPs) for sample collection, handling, and analysis; use of standard reporting units; and use of standardized procedures for data analysis and interpretation. These measures assure comparability of data among sites and over time.

Completeness is defined as "a measure of the amount of data collected from a measurement process compared to the amount that was expected to be obtained under the conditions of measurement" (Stanley and Verner, 1985). Data may be lost due to inability to collect the sample, sample destruction or loss in shipping or analysis, and analytical error. Additional data values may be deleted due to association with some aspect of "unacceptability" with respect to precision, accuracy, or detection limit or as the result of application of statistical outlier tests. The completeness objective for LTHMP is 80%; this objective has been established because dry wells or access restrictions occasionally preclude sample collection.

Each sample of surface and ground water consists of two parts: a one-gallon (3.8-L) sample collected in a plastic bottle for gamma spectrometric analysis and one-pint (500-mL) samples collected in glass bottles for ^3H analysis. The accuracy of the analytical methods is as follows:

Type of Analysis	LLD[1,2]	Accuracy @ 95% Confidence Interval[2]
Tritium Analysis		
Conventional	500	± 100% at 500 or ± 15% at 10^3
Enrichment	10	± 50% at 12 or ± 6% at 10^2
Gamma Emitters		
Range 60 to 2000 keV	5	± 80% at 6 or ± 5% at 10^2

[1] Estimated Lower Limit of Detection.
[2] Units of 10^{-9} µCi/mL = pCi/L.

4.3 Amchitka Island Projects, Alaska

4.3.1 Operational Area

Amchitka Island is of volcanic origin and is seismically very active. There are no active volcanos, but there is a rugged coastline that is subject to very active erosion. The western third of the island is mountainous, with elevations up to 366 meters (1200 feet). The eastern lowlands contain many lakes and ponds with few drainage connections and are covered by vegetation. The exposed mountainous west area is nearly bare and treeless, and vegetation occurs only in stream bottoms and flat, protected areas. However, the majority of the island is covered with grass. Plant productivity generally exceeds decay, producing peat that is sometimes several meters thick in the flats. Natural revegetation is strongly dependent on drainage.

The temperature on Amchitka is moderate, the record high and low being 65°F and 15°F respectively. Rain, wind and fog occur on the island much of the time. The only permanent land mammal is the Norway rat. At the time of these tests there was no human population. One hundred species of bird nest there, but only a few types of fish live on the island, although they are numerous.

4.3.2 Operational Activities

Amchitka Island, Alaska was the location for three underground nuclear tests. One of these tests (Project LONG SHOT) was conducted under the aegis of the Vela Uniform Program. Project LONG SHOT was conducted in a seismically active area to gather additional data for this program (AEC 1966). The other two tests were conducted as part of the weapons program. Project MILROW was a calibration test (AEC 1970) prior to the higher yield Project CANNIKIN which was a test of the Spartan warhead intended for use in the safeguard antiballistic missile system (AEC 1973).

4.3.2.1 LONG SHOT Event

Project LONG SHOT was detonated at 1100 hours, Alaska Standard Time (AST) on October 29, 1965 at a depth of 701 meters (2300 feet) below the ground surface. The yield for Project LONG SHOT was approximately 80 kt. From an examination of the initial monitoring data, all radioactivity was retained underground as was expected. However, two months later traces of radiation contamination began appearing in surface water. Eleven months later tritium (^3H) was detected in several ponds on the north edge of the surface ground zero (SGZ) pad that had been used for pumps for drilling mud. Tritium also was detected in a drainage ditch for the ponds. The highest level detected was 17×10^{-6} µCi/mL, less than the National Primary Drinking Water Regulations of 20×10^{-6} µCi/mL. The most likely explanation for this was upward seepage from the top of the chimney through stemming material or through the cement envelope around the emplacement hole casing and accumulation of tritium in the upper few hundred feet of rocks (AEC 1971).

4.3.2.2 MILROW Event

The SGZ for Project MILROW was south of the LONG SHOT test. The device was emplaced 1220 meters (4000 feet) below land surface and was detonated on October 2, 1969, with a yield of about 1000 kt. Rock falls were common within a two-mile radius of SGZ and there were numerous disturbances to stream flow. There was no indication that radioactivity had escaped from the test cavity.

4.3.2.3 CANNIKIN Event

The SGZ for Project CANNIKIN was northwest of the LONG SHOT test. It was detonated on November 6, 1971, at a depth of 1790 meters (5875 feet) below ground surface and had a yield of less than 5000 kt. There was no indication that radioactivity had escaped from the test cavity, but numerous rock falls, turf slips, and slides occurred. Small amounts of radioactive gases were found during drillback into the chimney. Also, elevated levels of tritium were found in some water sources. These elevated levels were attributed to gaseous radionuclides being pushed to the surface by water rising in the chimney.

The U.S. Public Health Service (PHS), Southwestern Radiological Health Laboratory in Las Vegas, Nevada (now EMSL-LV), conducted an offsite radiological monitoring program for each of these tests. Onsite monitoring was conducted by USGS and Teledyne Isotopes. In general the monitoring consisted of air and water sampling and measurement of gamma radiation using gamma-rate recorders and film badges or TLDs. The latter were used for both area and personnel monitoring. For the CANNIKIN event, because of the high yield, the monitoring network extended into Alaska, including sampling milk from dairies near

Anchorage. No radioactivity related to any of the tests was detected by this monitoring. The results for LONG SHOT are reported in reference PHS 1968, for MILROW in PHS 1969, and for CANNIKIN in EPA 1971.

After the transient effluents for Projects LONG SHOT and CANNIKIN mentioned above were observed, subsequent hydrological monitoring at the LONG SHOT site has shown that the decrease of tritium concentration in water is equal to or faster than normal radioactive decay, so the test cavity is not a continuing source of tritium effluents and diffusion may be occurring. At present there are no detectable emissions from the CANNIKIN test in the monitored sites.

4.3.3 Environmental Surveillance

4.3.3.1 Criteria

Because of the depth of burial of these three tests, it was expected that the radioactivity produced by them would be retained in the cavity melt or sorbed on rock surfaces, except for ^{3}H. Tritium in groundwater is not retarded by geologic media so it will be the first to move out of the cavities as demonstrated by its appearance following the LONG SHOT and CANNIKIN tests. The only probable pathway for radioactivity to migrate from the test cavities is via groundwater. For the ^{3}H that migrated to the surface following the LONG SHOT event, the possibility of uptake by lichens or by fish exists, but analyses of samples of these have not shown any significant uptake. Therefore, surveillance of groundwater systems on the island is the method of choice for detection of migration of radioactivity from the test cavities.

Although the area around the test sites on Amchitka Island was uninhabited at the time of the tests, it was visited by native people occasionally and is presently occupied by military personnel. Because of continued presence of tritium in some of the water sources near the LONG SHOT surface ground zero and the transient contamination near the CANNIKIN site, ground and surface water monitoring to ensure that contamination is not continuing and that the existing contamination is not spreading is required. Furthermore, since Amchitka Island is considered to be seismically active, the possibility of earthquakes opening new paths for transport of radioactivity from the test cavities exists and surveillance to detect any such event is necessary. Therefore, in accordance with DOE/NV policy, together with the aquifer transport uncertainties and possibility of seismic activity, an environmental surveillance program is necessary. Amchitka Island with the locations of the three tests and the background water sampling locations is shown in Exhibit 4-3-1.

4.3.3.2 Surveillance System Design

Because the only pathway for transport of radioactivity from this site is via groundwater, groundwater monitoring is used supplemented by surface water sampling. Also, tritium is the isotope that will move out of the test cavity first because it becomes part of the water molecule, so tritium is the choice for analysis along with gamma spectrometry to detect any other migrating radionuclides. The LTHMP began in 1972, and the locations on Amchitka Island were added to the program in 1977.

The original hydrologic sampling network on Amchitka was established by the Palo Alto Laboratories of Teledyne Isotopes (Essington 1971). The background or control sampling locations are shown in Exhibit 4-3-1 and listed in Table 4-3-1 together with other sites that have been sampled since the Program began. Sampling locations for LONG SHOT are

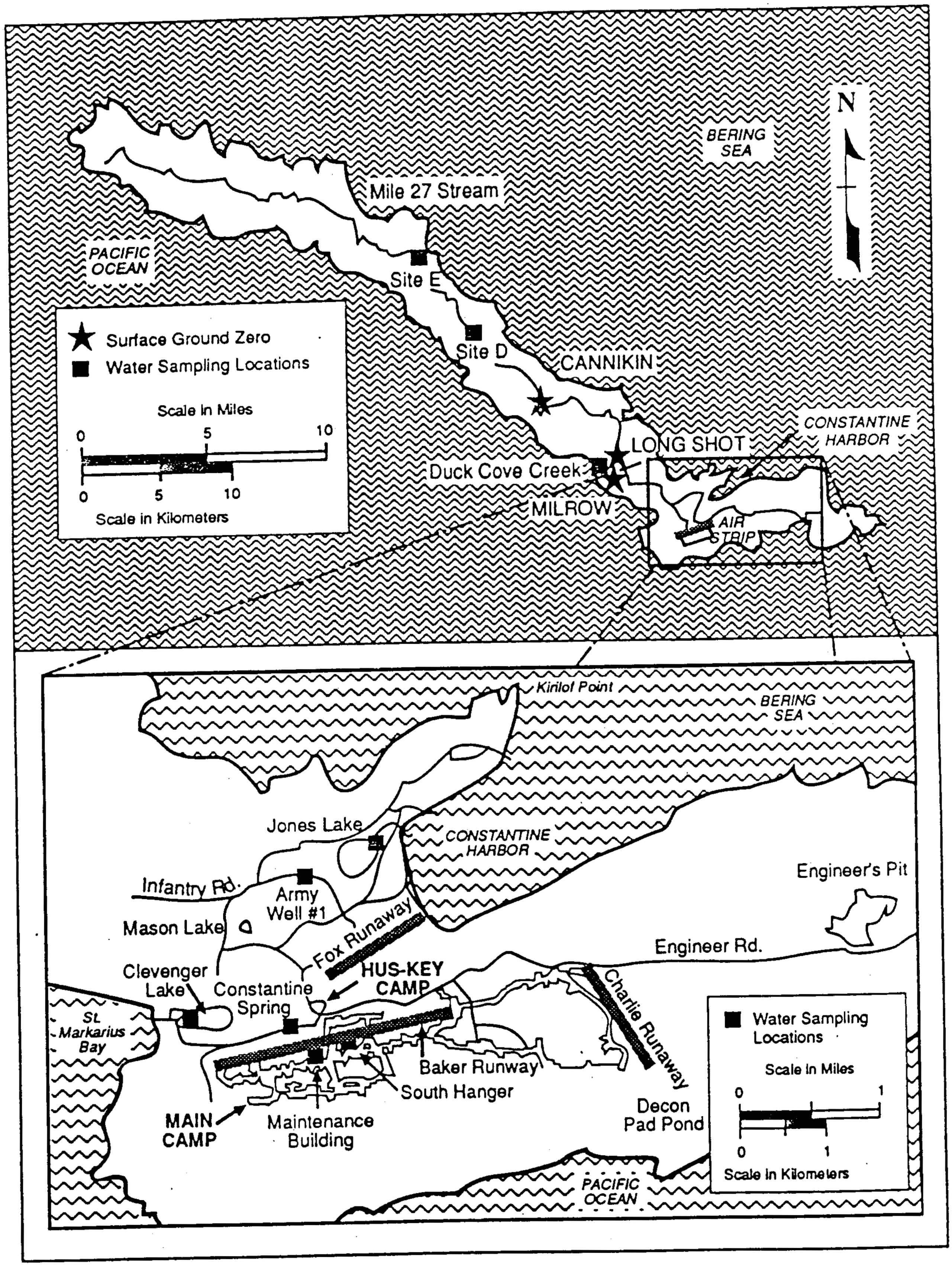

Exhibit 4-3-1 Amchitka Island, Test Sites, and Background Sampling Locations

shown in Exhibit 4-3-2 and listed in Table 4-3-2. Those for MILROW are shown in Exhibit 4-3-3 and listed in Table 4-3-3, and for CANNIKIN are shown in Exhibit 4-3-4 and listed in Table 4-3-4.

4.4 Project RIO BLANCO, Colorado

Project RIO BLANCO was part of the PLOWSHARE Program and was sponsored by CER Geonuclear Corporation (CER) of Las Vegas, Nevada, under a joint venture agreement with the Equity Oil Co. of Salt Lake City, Utah. RIO BLANCO was an experiment designed to stimulate gas flow in a thick section of low permeability, lenticular, gas-bearing sands in the Piceance Creek Basin of northwestern Colorado. The experiment involved the sequential detonation of three 30-kt nuclear explosives emplaced in a vertical bore hole that transected numerous gas-bearing sandstones that were too "tight" to be fractured economically by conventional methods such as hydrofracture (AEC 1973).

4.4.1 Operational Area

The RIO BLANCO site is in the Piceance Basin, a sparsely populated region in Rio Blanco County in northwestern Colorado. The area is at a relatively high altitude varying from about 1520 to about 2590 meters (5000 to 8500 feet). The climate is semi-arid with average annual precipitation varying from 23 to 51 cm. The main industry in the region is raising livestock, with limited agriculture directed to growing feed crops. There has been some development of mineral resources centered primarily in the Rangely oil field that is 48 to 56 kilometers (30 to 35 miles) northwest of the RIO BLANCO site and in the Rio Blanco gas field to the east of the site. The area is rich in oil shale and sodium minerals but both of these are essentially undeveloped. The closest communities are Meeker, Rangely, Grand Valley, and Debeque, all about 48 kilometers from the site. The steep, southeast-facing slopes are dry, rocky, and semibarren while sagebrush/rabbitbrush occurs in the bottomland along Fawn Creek and the small ravines leading into it. The chief large animal species are Rocky Mountain mule deer, elk, black bear, and mountain lion. There are numerous small mammals, game birds, migratory waterfowl, and game fish. No endangered species were known to be present (AEC 1972).

The SGZ for the emplacement well is in Section 14, Township 3S, Range 98W at 2020 meters (6630 feet) above mean sea level on an irregular area of 3.2 acres on Fawn Creek. Three nuclear devices were set in a single well-bore at depths of 1780, 1900, and 2040 meters (5838, 6230, and 6689 feet) through a thick section of low permeability, lenticular, gas-bearing sandstones of the Fort Union and Mesa Verde formations. There were more than 15 separate sand lenses present and oil shale down to 700 meters (2300 ft). There was an estimated 74 billion standard cubic feet of natural gas per square mile at the RIO BLANCO site.

4.4.2 Operational Activities

The three 30-kt (design yield) nuclear devices were detonated at approximately 1000 hours Mountain Daylight Time on May 17, 1973. The planned interval of 10 microseconds between each detonation was apparently achieved. Radiation monitoring showed that all radioactive particulates from the test area were retained in the chimney except during drillback operations. During the last stages of the RB-AR-2 entry drilling some tools became contaminated with low levels of ^{137}Cs and ^{90}Sr that were not spread beyond the SGZ area because of the strict

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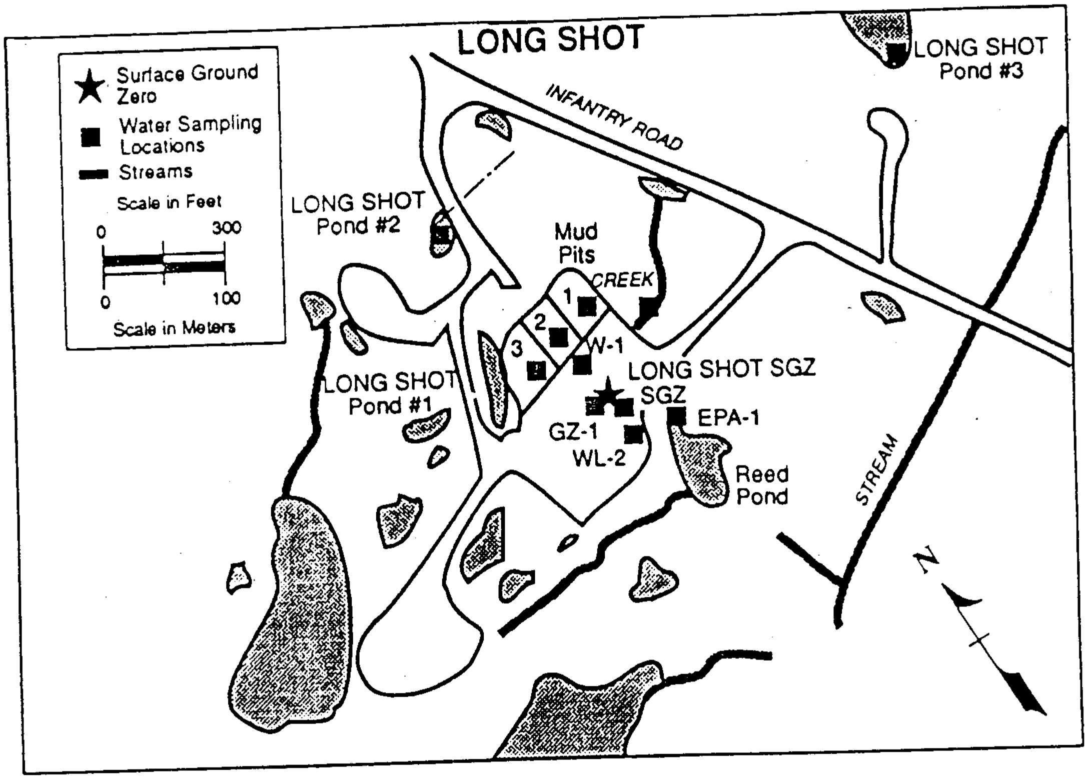

Exhibit 4-3-2 Water Sampling Locations for Project LONG SHOT

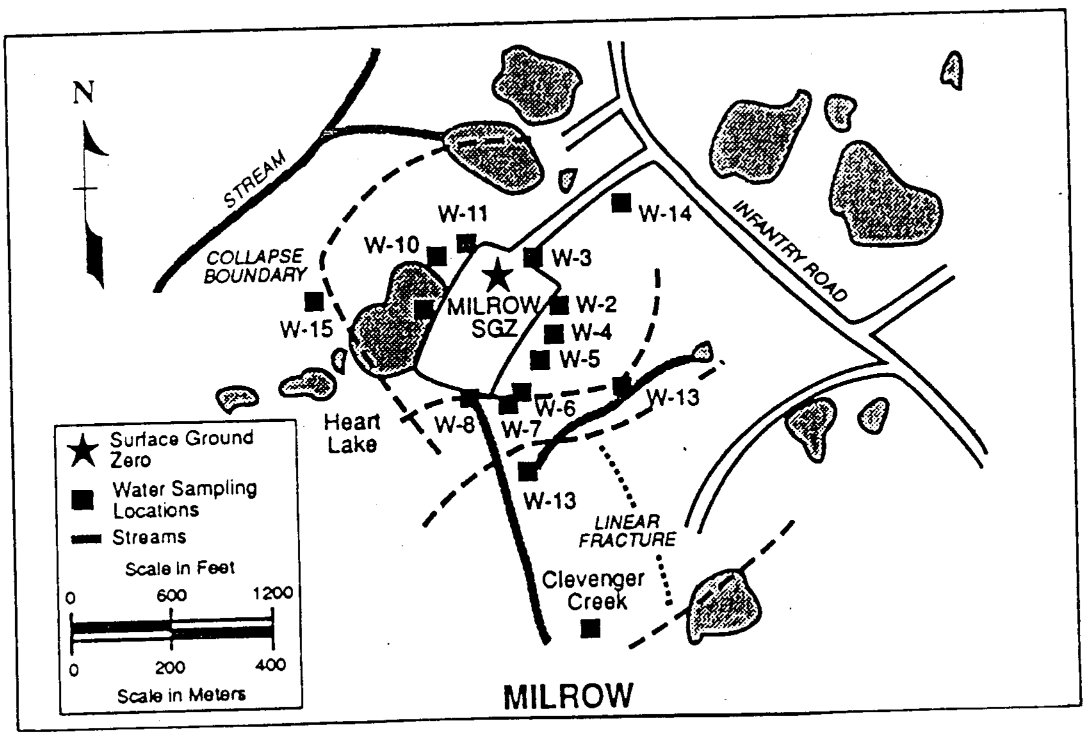

Exhibit 4-3-3 Water Sampling Locations for Project MILROW

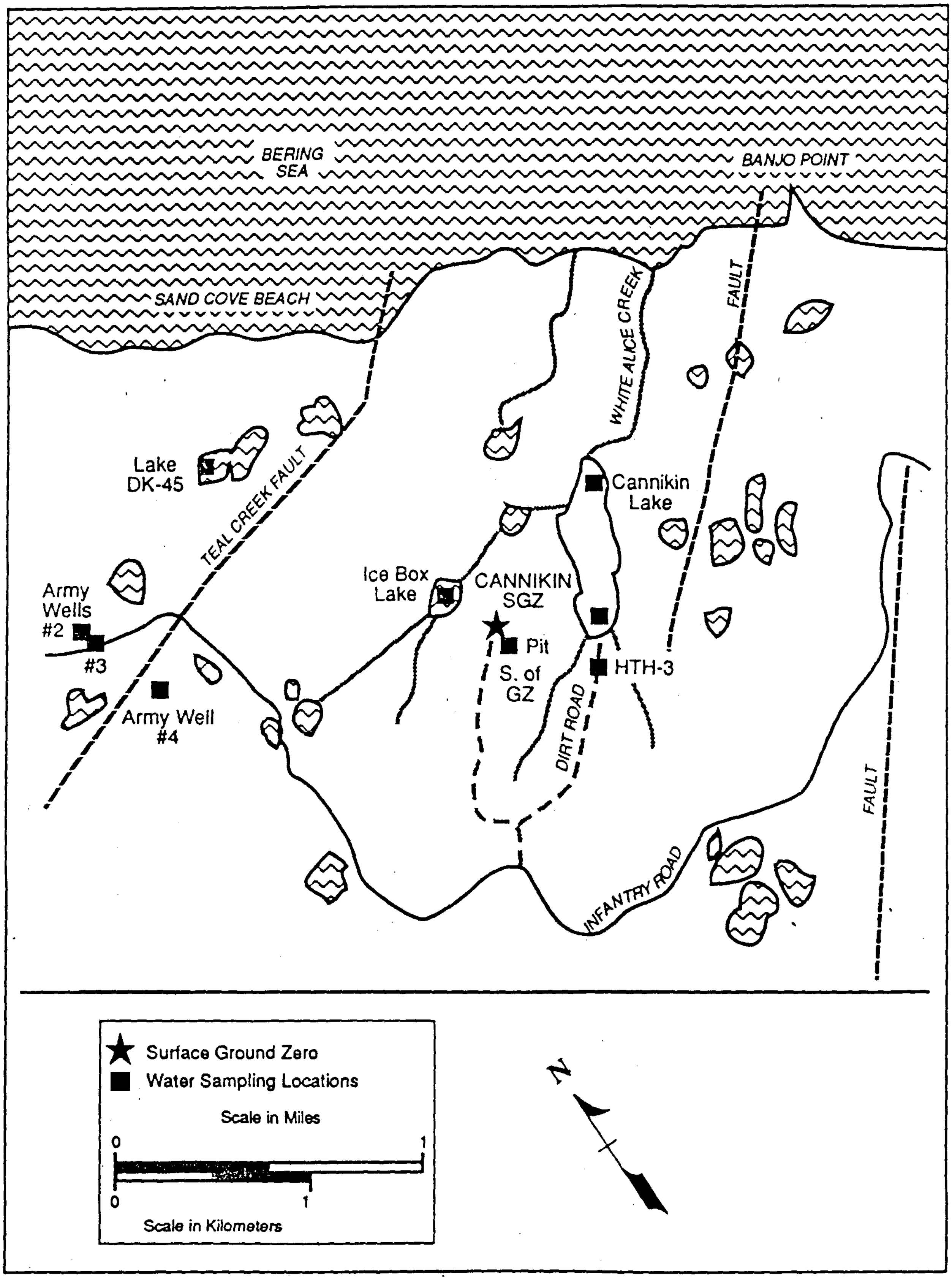

Exhibit 4-3-4 Water Sampling Locations for Project CANNIKIN

Table 4-3-3 Water Sampling Locations for Project MILROW

LOCATION	SAMPLING DEPTH (FT)	FIRST SAMPLED	LAST SAMPLED	PUBLIC ACCESS
Clevenger Creek	Surf	1977		Yes
Heart Lake	Surf	1977		Yes
Well W-2	1	1977		Yes
Well W-3	3.7	1977		Yes
Well W-4	2.5	1978		Yes
Well W-5	2.8	1977		Yes
Well W-6	3.1	1977		Yes
Well W-7	2.4	1978		Yes
Well W-8	5.1	1977		Yes
Well W-10	6.4	1977		Yes
Well W-11	4.8	1977		Yes
Well W-13	3.4	1978		Yes
Well W-14	--	1985		Yes
Well W-15	3.7	1977		Yes
Well W-16	--	1983		Yes
Well W-17	--	1984		Yes
Well W-18	1.7	1978		Yes
Well W-19	--	1989		Yes

Table 4-3-4 Water Sampling Locations for Project CANNIKIN

Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
Cannikin Lake N.	Surface	1977		Yes
Cannikin Lake S.	Surface	1977		Yes
DK-45 Lake	Surface	1983		Yes
Ice Box Lake	Surface	1977		Yes
Pit South GZ	Surface	1977		Yes
White Alice Creek	Surface	1977		Yes
Well HTH-3	140	1977		Yes

cleanup procedures. Some tritiated production water was also retrieved that was disposed of in Fawn Creek Government Well No. 1. No personnel had exposures higher than background as measured by TLDs, and no radioactivity was detected in urine samples.

No fault movement was observed, although several faults were present in the area. The ground movement was measured at an equivalent earthquake magnitude of about 5.4. Post-shot examinations revealed less structural damage than had been predicted; minor damage to residential structures totaled less than $14,000 as of July, 1973. An increase in yield in some area springs was noted, old springs that had been dry for decades were revived, and others dried up. Also, several creeks had flows that were several times normal and lasted for some time (AEC 1973).

The only effluents from this site occurred during the production test phases drillback. During the production tests and flaring operations, 1020 Ci of ^{85}Kr and 75 Ci of ^{3}H were released to the atmosphere and 178 Ci of ^{3}H plus mCi quantities of ^{90}Sr and ^{137}Cs were injected into the disposal well FCG No. 1. Monitoring during Project RIO BLANCO was performed by the Eberline Instrument Corporation, Colorado Health Department, and U.S. Geological Survey (USGS) to ensure that effluent releases did not continue. There have been no effluents since the drillback activity in 1973 and the production tests in 1974.

4.4.3 Environmental Surveillance

4.4.3.1 Criteria

Because of the depth underground that this test was conducted, it was predicted that radioactivity produced by the RIO BLANCO event would be retained in the cavity melt or sorbed on rock surfaces except for tritium. Tritium in groundwater is not retarded by geologic media so it would be the first to move out of the cavity as stated above. Prior to execution of this test, the USGS submitted a study group report that predicted "It is expected that the chimney will be in the Mesa Verde and Fort Union rocks. Groundwater in this section of low permeability lenticular gas sands probably does not move significantly. Transport of radionuclides by moving groundwater in these rocks will be insignificant." Even if naturally occurring earth activity changed the rate and direction of groundwater movement, contamination of drinking water with tritium would remain the principal pathway to humans. Pathways through vegetation and through grazing animals would permit additional dilution of any hazard that might exist.

A DOE/NV panel of consultants expressed some concern over possible seepage of radioactive gases in the annulus of the emplacement well, but this would also be a minor pathway (ERDA 1975).

Although predictions suggested that significant levels of tritium from the test cavity would not reach the accessible environment in concentrations sufficient to create a hazard, prudence requires that groundwater monitoring be conducted to confirm that transport of radioactivity from the test cavity is not occurring. This is particularly true because seismic or other natural activity may occur in this geologically young area to cause a more rapid migration of groundwater. The location of the site and the current sampling locations are shown in Exhibit 4-4-1.

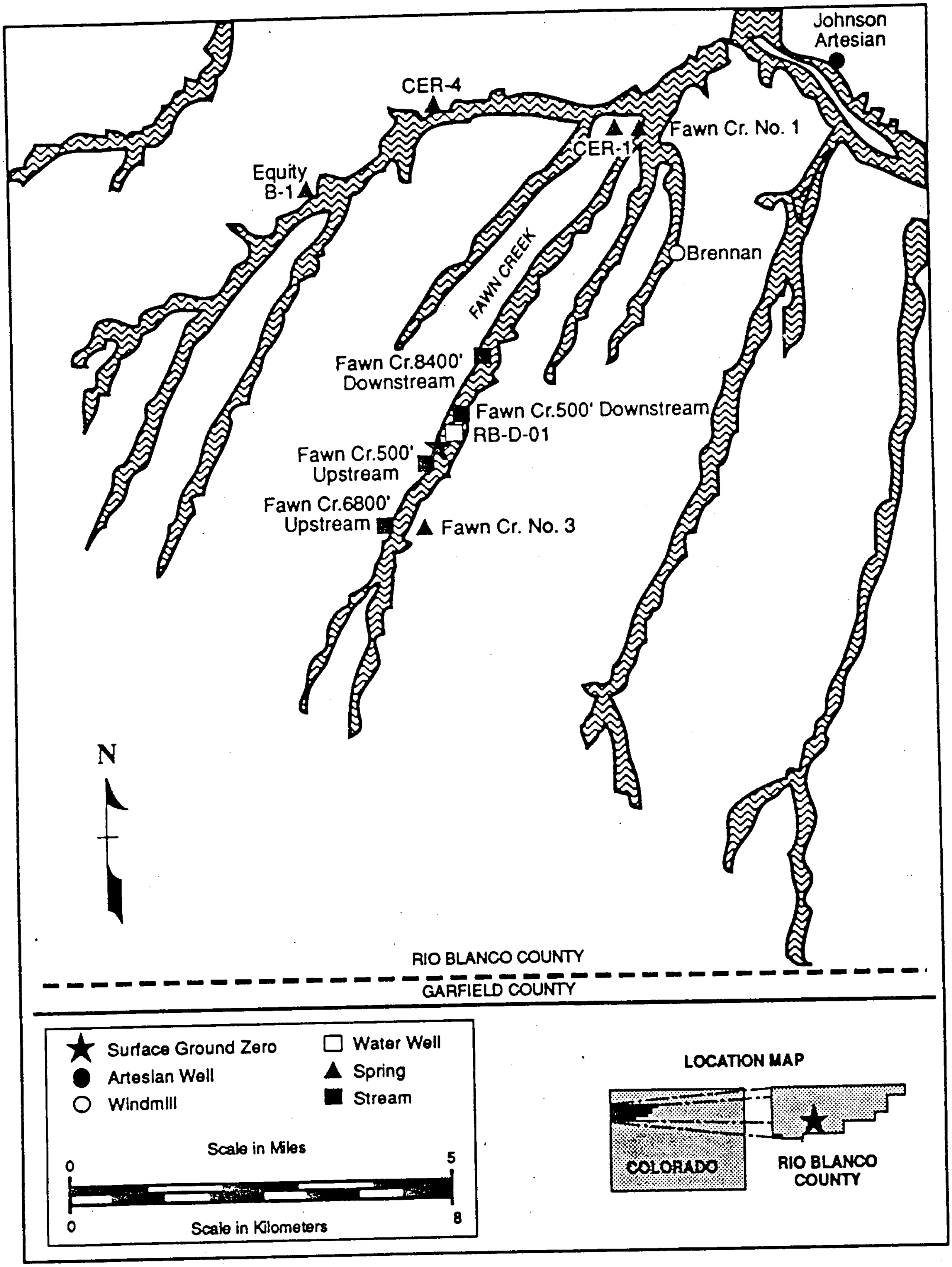

Exhibit 4-4-1 Location of RIO BLANCO and Water Sampling Points

4.4.3.2 Surveillance System Design

The original hydrologic sampling network for RIO BLANCO was established by the DOE/NV with assistance from DRI, USGS, and CER. The USGS had performed pre-event and post-event comparison of radionuclide concentrations in surface and groundwater in the area surrounding the site. Some of those locations were proposed as suitable for the LTHMP and were approved by the Hydrologic Program Advisory Group of the DOE/NV. The water sampling locations are shown in Exhibit 4-4-1 and are listed in Table 4-4-1 together with other sites that have been sampled since the Program began.

Table 4-4-1 Water Sources Sampled Annually at the RIO BLANCO Site

Name and Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
Rio Blanco, CO				
B-1 Equity Camp	Surface	1977		Yes
Brennan Windmill	--	1977		Yes
CER 1 Black Sulfur	Surface	1977		Yes
CER 4 Black Sulfur	Surface	1977		Yes
Fawn Creek #1	Surface	1972		Yes
Fawn Creek #3	Surface	1972		Yes
Fawn Creek				
6800 Ft Upstream	Surface	1977		Yes
500 Ft Upstream	Surface	1977		Yes
500 Ft Downstream	Surface	1977		Yes
8400 Ft Downstream	Surface	1977		Yes
Johnson Artesian Well	--	1977		Yes
RB-D-01	1450	1977		No
RB-D-03	--	1987		No
RB-S-03	--	1987		No

4.5 Project RULISON, Colorado

Project RULISON was part of the PLOWSHARE Program, a program to develop peaceful uses for nuclear explosives. The objective of Project RULISON was to determine the feasibility of stimulating the flow of natural gas in a low-permeability rock formation by use of a nuclear explosive. Project RULISON was performed under a joint industry/government agreement and differed from Project GASBUGGY in that the device used had a larger yield and that the formation in which it was detonated was sandstone interbedded with shale (DOE 1984) rather than all shale.

4.5.1 Operational Area

The Project RULISON site is located in Section 25, Township 7S, Range 95W, in south-central Garfield County, Colorado. It is situated on the north slope of Battlement Mesa on the upper reaches of Battlement Creek. The site elevation is 2.5 kilometers (8200 ft) above mean sea level. The nearest large city is Grand Junction, approximately 64 kilometers (40 miles) southwest. The nearest city with substantial industry is Rifle, 19 kilometers (12 miles) to the northeast. The closest town is Grand Valley, 10 kilometers (6 miles) to the northwest of SGZ.

Approximately four permanent habitations were located closer than 5.6 kilometers (3.5 miles). The average annual precipitation at the RULISON site was 50 cm (20 in) and the temperature range was from -23° C to +37° C. The RULISON site is in a mountain valley that trends north-northwest/south-southeast, resulting in a pronounced drainage wind regime. Movement of air away from SGZ is primarily controlled by three wind regimes; Valley drainage winds and daily upslope winds in both the Battlement Creek Valley and the Colorado River Valley are two of the winds. Regional gradient winds form the third regime and blow generally to the east-northeast above topographical features throughout the year.

4.5.2 Operational Activities

Project RULISON was divided into three phases. In phase I the preshot exploratory well (R-EX) and the emplacement hole (R-E) were drilled. Gas production tests were done using R-EX to establish pretest conditions, and investigation of the geologic and hydrologic condition of the site was completed. Phase II of Project RULISON included surface construction and emplacement followed by detonation on September 10, 1969, at 1500 hours MDT in the Mesa Verde formation at a depth of 2570 meters (8430 feet). The yield of the device was about 40 kt. Little ground motion occurred and nearby structural damage was slight and less than was predicted. Phase III of the experiment was initiated in April of 1970 and involved controlled drillback into the cavity followed by flow testing of the gas to determine the cavity size and the rate and volume at which the natural gas could be produced.

The PHS was responsible for offsite monitoring prior to, during, and after test execution. During the actual detonation all radioactivity was contained. The PHS reported that its monitoring program detected no increase in radionuclides and no detectable tritium above pretest levels in surface and subsurface waters. No fission products were detected in air samples and ground monitoring, and personal dosimeters showed no increase over background levels. Post-test radionuclide concentrations in milk samples were similar to those in pre-test samples (PHS 1971).

Radioactivity was released to the environment during the flaring operation in December 1971 as expected. The releases included 321 Ci of ^{85}Kr, 385 Ci of ^{3}H, 0.68 Ci of ^{14}C, and 30 μCi of ^{203}Hg over the three-week period of the flaring. The only residual contamination was in areas of known spills and the close-in area contaminated with fallout or snowout from the flare stack (AEC 1973). All activities were well documented and controlled, and no significant exposures to the general population occurred. The only known effluents from this site occurred during the production test phases. There are no known effluents at present.

4.5.3 Environmental Surveillance

4.5.3.1 Criteria

Because of the depth underground that this test was conducted, it was predicted that radioactivity produced by the RULISON event would be retained in the cavity melt or sorbed on rock surfaces except for tritium. Tritium in groundwater is not retarded by geologic media so it would be the first to move out of the RULISON cavity. Since groundwater flow velocity is only 0.3 m/day, predictions were that it would take many years for any contaminated water to reach the nearest producing water well. Even if naturally occurring earth activity changed the rate and direction of groundwater movement, contamination of drinking water with tritium would remain the principal pathway to humans. Pathways through vegetation and through grazing animals would permit additional dilution of any hazard that might exist. The location of the RULISON site and current monitoring locations are shown in Exhibit 4-5-1.

4.5.3.2 Surveillance System Design

The original hydrologic sampling network for RULISON was established by Teledyne Isotopes and the USGS to provide pre-event and post-event comparison of radionuclide concentrations in surface and groundwater in the area surrounding the site. The original sampling locations were proposed by USGS and were approved by the Hydrologic Program Advisory Group of the DOE/NV. The water sampling locations are shown on Exhibit 4-5-1 and are listed in Table 4-5-1 together with other sites that have been sampled since the Program began.

Table 4-5-1 Water Sources Sampled Annually at the RULISON Site

Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
Anvil Points CO				
Bernklau Ranch	Spring	1972	1977	Yes
Grand Valley CO				
Battlement Creek	Surface	1972		Yes
City Spring	Surface	1972		Yes
Gardner Ranch	120	1972		Yes
Spring NW of GZ	Spring	1972		Yes
CER Test Well	44	1972		No
Rulison CO				
Bingman Ranch	--	1972	1977	Yes
Hayward Ranch	140	1972		Yes
Potter Ranch	Surface	1977		Yes
Schwab Ranch	140	1972		Yes
Sefcovic Ranch	87	1975		Yes

4.6 Project DRIBBLE, Mississippi

Project DRIBBLE was a part of the Department of Defense Program named Vela Uniform. This program involved a series of experiments on and off the NTS designed to improve this country's capability to detect, identify, and locate underground nuclear detonations. In particular, Dribble was an experiment to determine the effect of decoupling on the seismic signal generated by an underground nuclear explosives test. In decoupling, the device is detonated in a large cavity rather than in an emplacement well.

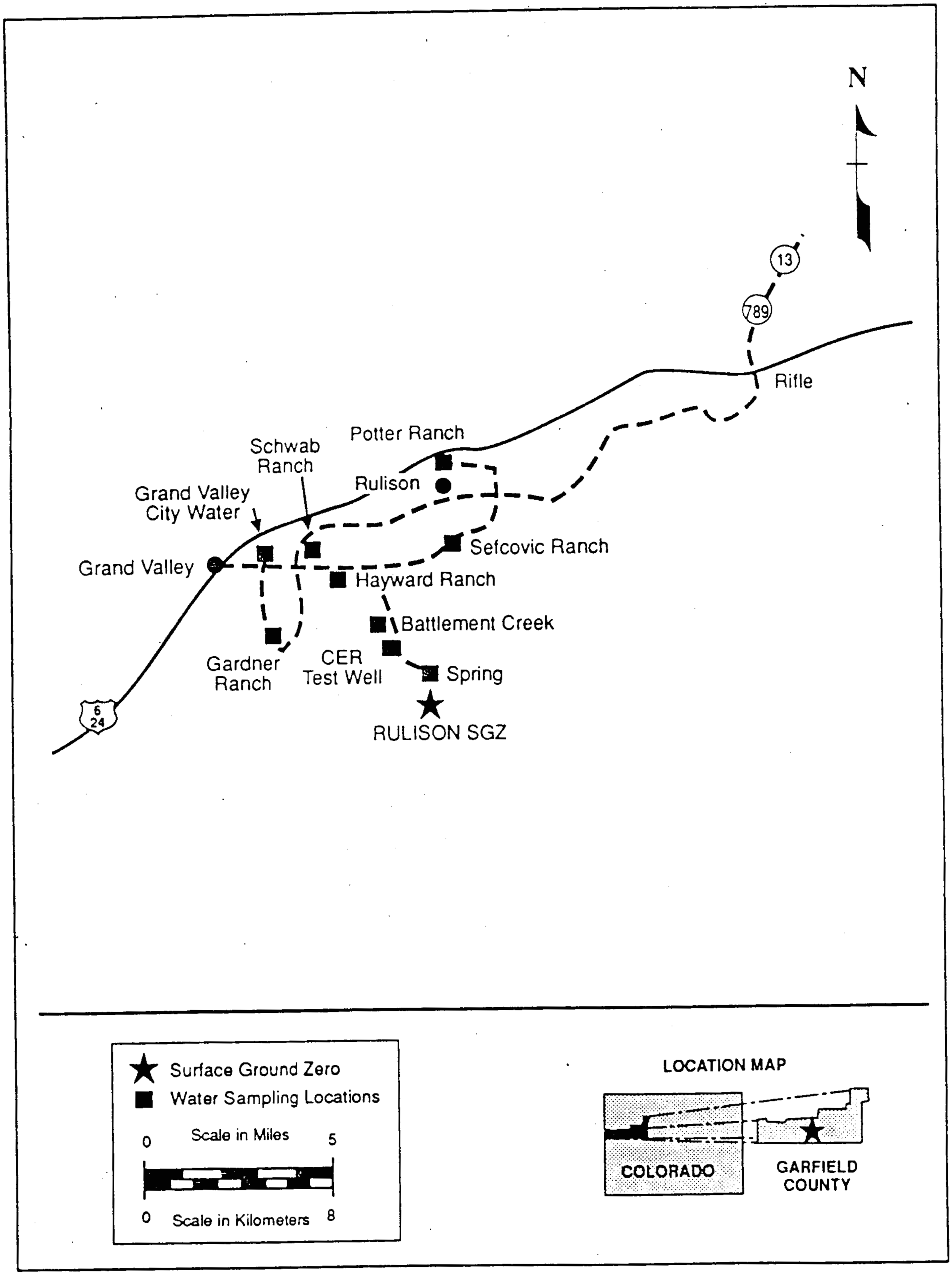

Exhibit 4-5-1 Location of Project RULISON and Water Sampling Locations

The technical requirements for Dribble could best be met by preparing a site in a large body of salt that was not too deep, that had relatively pure salt, and that was located in an area where seismic instruments could be placed at considerable distances from the site in several directions. Since these requirements could be met in a salt dome, all known data about domes in the Gulf states, where most U.S. domes are located, was gathered. The Tatum Dome in Lamar County, MS, seemed to meet the specifications best (AEC 1964).

4.6.1 Operational Area

The DRIBBLE events occurred in the Tatum Salt Dome, Tatum Dome Leasehold, that contains approximately 1470 acres in Sections 11, 12, 13, and 14, Township 2N, Range 16W, located in Lamar County in southcentral Mississippi about 34 kilometers (21 miles) southwest of Hattiesburg as shown in Exhibit 4-6-1. The site is in the low hills of the piney woods area of the Gulf Coastal Plain. Narrow, flat-topped ridges and valleys trend south-southeast to the Gulf of Mexico. Frequent perennial and intermittent streams dissect the terrain, and there are numerous swamps. Groundwater seepage contributes significantly to the high base flow of local streams. The major surficial hydrological features are the Grantham and Half Moon creeks. The Dome is comprised of 90 percent NaCl and 10 percent $CaSO_4$ and is overlain by a caprock of anhydrite, about 140 meters (460 feet) thick, and that is overlain by limestone that is another 30 to 46 meters (100 to 150 feet) thick. The water content is only 0.001 percent by weight. The salt surface is 457 meters (1500 feet) below ground surface and is 1600 meters (1 mile) in diameter at its top.

The climate is humid and semi-tropical with an average rainfall of 150 cm (59 in) per year. There were 980 people within 7.2 kilometers (4.5 miles) in 1964 when the first test took place.

4.6.2 Operational Activities

Project DRIBBLE consisted of four explosions conducted within the salt dome. Two of these were nuclear explosives tests: SALMON and STERLING. The other two tests were gas explosions.

4.6.2.1 SALMON Event

SALMON was a nuclear test that was detonated at 1000 hours Central Standard Time on October 22, 1964 with a yield of about 5 kt. It was designed to create the cavity in which the three other explosions were to occur. Following the SALMON test, monitoring by PHS detected no activity above background using ground or aerial monitors or on gamma-rate recorders. No exposure was detected on dosimetry badges. Some milk samples collected on December 4 contained ^{131}I, but this was due to fallout from a Chinese atmospheric test conducted on October 16 (PHS 1966). After the test, contaminated water containing 38 Ci of beta/gamma activity and 3200 Ci of tritium was injected into aquifer 5 through disposal well HT-2.

4.6.2.2 STERLING Event

STERLING was a nuclear test that was detonated at 0615 hours CST on December 3, 1966 with a yield of about 380 tons. There were then two gas (non-nuclear) explosions, using oxygen and methane mixtures, of about 315 tons each. They were DIODE TUBE, that was fired on February 2, 1969, and HUMID WATER, fired on April 19, 1970.

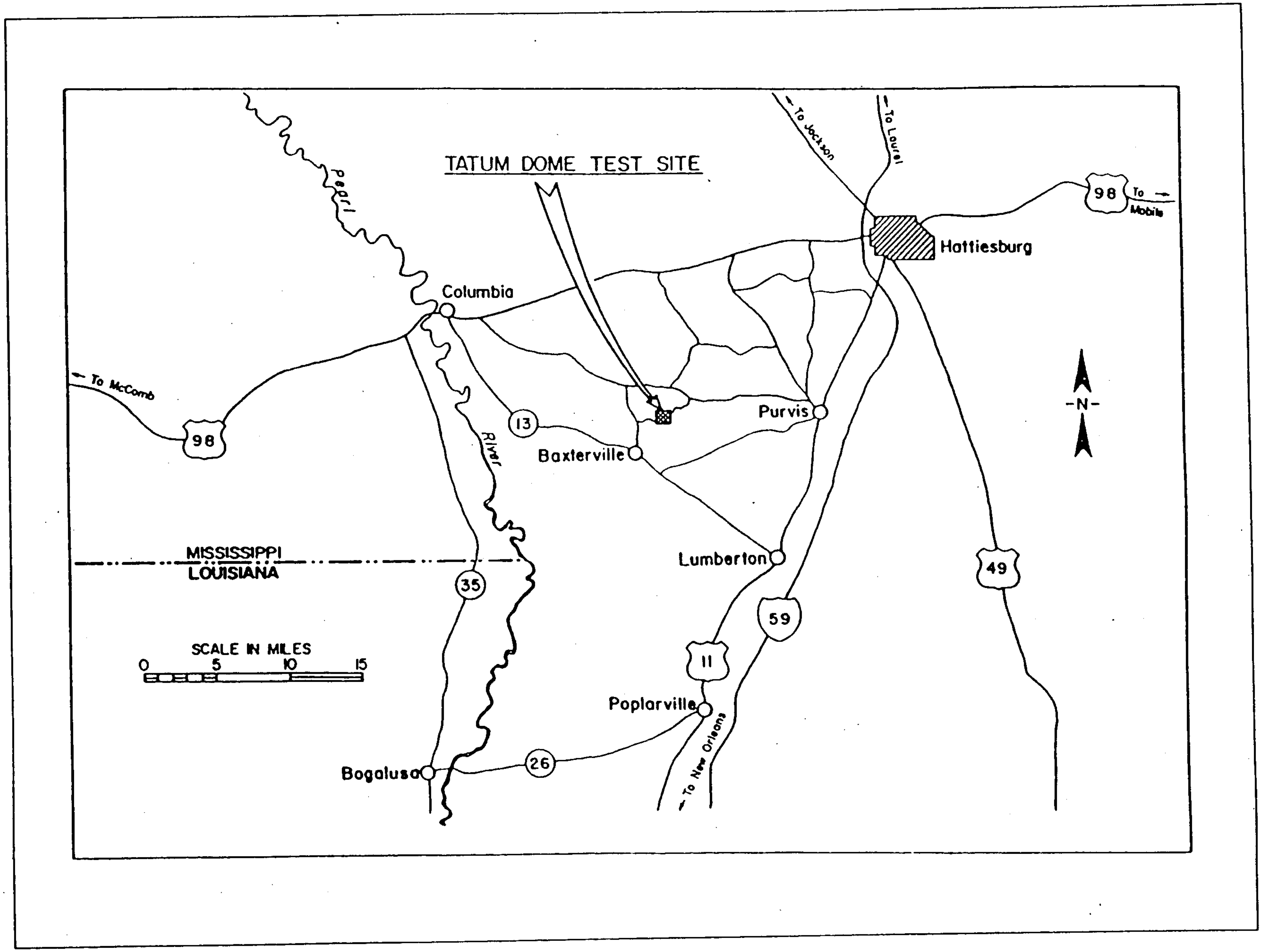

Exhibit 4-6-1 Location of the Tatum Dome Test Site

Offsite monitoring by the PHS after the STERLING event in the Tatum Salt Dome also detected no radioactivity above background levels in air, water, milk, or vegetation samples collected within an 80-kilometer (50-mile) radius nor was any exposure detected on personnel or area film badges (PHS 1968).

The tests were completed in April 1970 and local contamination (onsite) was cleaned up in 1971 so the area could be released for public use. Contaminated soil and water were placed in the DRIBBLE cavity and the access well was plugged. Contaminated equipment and other materials were shipped to the NTS for burial. Following these activities, the LTHMP was instituted to provide continuous surveillance of the site.
The only effluents from this site occurred during re-entry drilling during the test phases as summarized above. There are no known effluents at present.

4.6.3 Environmental Surveillance

4.6.3.1 Criteria

Since the salt in the Dome is essentially impermeable and is so far below ground surface, and since monitoring data after the tests indicated all radioactivity was contained within the test cavity, then the only pathway to man is via groundwater. Consequently, groundwater monitoring is the only requirement for surveillance of this test site.

With the high rainfall rate in this area, it is to be expected that wetlands, flowing streams and shallow aquifers would exist. All of these are present. The many groundwater aquifers at the Tatum Dome Site are shown in Table 4-6-1. Although improbable, the four tests conducted within the dome could have opened cracks for seepage of test-produced radioactivity. Another route of escape for the radioactivity in the cavity is through the emplacement holes and post-shot holes that penetrate the cavity if the plugging activities had not produced perfect seals. In either case, the radionuclide most likely to first appear outside the cavity will be tritium.

Table 4-6-1 Aquifers On and Around Tatum Dome

Aquifer	Flow Rate (ft/yr)	Direction of Flow
Surficial	--	Follows surface contour
Local	--	Probably to southwest
Caprock	--	Southwest
Aquifer 1	4	Southwest
Upper 2	80	East-northeast*
	160	South-southwest
Lower 2	80	East*
	40	Northeast
Upper 3	6	East-northeast
Aquifer 4	1	South-southwest
Aquifer 5	3	North-northeast

4.6.3.2 Surveillance System Design

The original sampling sites as assigned by the Hydrologic Program Advisory Group are listed in Table 4-6-2 and are shown on Exhibits 4-6-2 and 4-6-3, together with other sites that have been sampled since the Program began.

4.6.4 Additional Monitoring at Tatum Dome

Anomalous tritium concentrations in water samples from the Half Moon Creek Overflow Pond, and other locations, led to a comprehensive study of the surface ground zero area on Tatum Dome in 1978 to delineate the source of the contamination. Four-inch diameter holes were augured to the shallow groundwater table on 25-, 50-, and 100-foot grids over the ground zero area. Analysis for tritium in soil and water samples from these holes revealed a pattern of contamination of limited extent as shown in Exhibit 4-6-4. The contamination does not extend to great depth and is attributed to tritium brought back to the surface during early drillback operations (DOE 1978). At present, detectable levels of tritium are found in wells HM-L and HM-S at levels of less than 50 percent of the U.S. Drinking Water Regulations. Elevated levels are also found in three of the hydrological monitoring holes (HMH) augured near ground zero, namely, HMH-1, HMH-2 and HMH-5. The water in the HMH holes is not potable and that in HM-S and HM-L is not available to the public. The location of the HMH holes and HM wells is shown on Exhibits 4-6-3 and 4-6-5.

At times, because of public concern, additional samples are taken. In most cases, the additional samples have just been water from private wells. In 1990, however, public concern led to a congressional request for a more comprehensive study of the site, including an epidemiological study. The Centers for Disease Control was given the responsibility for epidemiology, whereas EMSL-LV was responsible for collecting additional samples. These latter included water samples from five more hydrologic monitoring holes (HMH) emplaced north of the previous HMH holes to detect any movement of the contaminated water. Other samples were collected from 10 private wells, and samples of garden vegetables and soil, soil from the ground zero area, fish from the creeks, deer meat, turkey meat, milk, moisture in air, and urine from residents were collected for tritium analysis, gamma spectrometry, and analysis of strontium-90 and plutonium. All results of analysis for radioactivity outside the Tatum Dome immediate area were at background levels. Also, analysis of water from the potable aquifers at the site for the RCRA panel of organic and inorganic substances showed only traces of a few organics at less than allowable levels. A complete description of the 1990 study is in reference EPA 1990.

Table 4-6-2 Water Sources Sampled Annually at Project Dribble

Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
COLUMBIA, MS				
CITY WELL 64B	--	1972		YES
N. LUMBERTON, MS				
CITY SUPPLY	--	1975	1981	YES
LUMBERTON, MS				
CITY WELL 2	780	1972		YES
PURVIS, MS				
CITY SUPPLY	900	1972		YES
BAXTERVILLE, MS				
CITY WELL	150	1972		YES
HALF MOON CREEK	SURF	1972		YES
LOWER LITTLE CREEK	SURF	1972		YES
ANDERSON, B.R.	70	1980		YES
ANDERSON, H.	70	1980		YES
ANDERSON, R.L.	90	1972		YES
BRYANT, L.J.	SURF	1979	1979	YES
CHAMBLISS, B.	250	1980		YES
DANIELS, W.	80	1972		YES
KELLY, G.	350	1980		YES
LOWE, M.	100	1972	1984	YES
MILLS, A.C.	350	1980		YES
MILLS, R.	70	1980		YES
READY, R.	75	1972		YES
SPEIGHTS, T.	35	1972	1986	YES
ASCOT 2	1950	1975		NO
HALF MOON OVERFLOW	SURF	1972		YES
SHELL 1	--	1972	1972	YES
WELL E-7	920	1972		NO
WELL HM-1	370	1980		NO
WELL HM-2A	300	1980		NO
WELL HM-2B	322	1980		NO
WELL HM-3	321	1980		NO
HMH-1	11	1978		YES
HMH-2	11	1978		YES
HMH-3	9	1978		YES
HMH-4	5	1978		YES
HMH-5	8	1978		YES
HMH-6	5	1978		YES
HMH-7	6	1978		YES
HMH-8	9	1978		YES
HMH-9	5	1978		YES
HMH-10	8	1978		YES
HMH-11	8	1978		YES

Table 4-6-2 Water Sources Sampled Annually at Project Dribble (cont.)

Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
WELL HM-L	140	1980		NO
WELL HM-L2	--	1981		NO
WELL HM-S	25	1980		NO
WELL HT-1	1230	1972	1979	NO
WELL HT-2C	355	1972		NO
WELL HT-2M	--	1972	1974	NO
WELL HT-4	400	1972		NO
WELL HT-5	600	1972		NO
WELL PS-3	110	1978	1979	NO
POND W OF GZ	SURF	1972		YES
REECo PIT A	SURF	1980		YES
REECo PIT B	SURF	1980		YES
REECo PIT C	SURF	1980		YES
SALT DOME TIMBER WELL	--	1984		YES
TATUM DOME HUNT CLUB	--	1987		YES

4.7 Project FAULTLESS, Nevada

The tests at the NTS have, for the most part, been limited in yield because of multi-story buildings in nearby communities that could be affected by high-yield nuclear tests.Since the testing laboratories had expressed a need to conduct high yield tests, areas suitable for such a purpose were investigated. Project FAULTLESS was designed as a calibration test for an area in Central Nevada, north of the NTS, named the Central Nevada Supplemental Test Area.

4.7.1 Operational Area

The Central Nevada Supplemental Test Area is located approximately 18 miles north of the Blue Jay Maintenance Station in the Hot Creek Valley as shown in Exhibit 4-7-1. The Project area is in the Basin and Range physiographic province and in the southwestern Bolson groundwater province. The area is typically characterized by ranges of mountains separated by broad valleys that, in large part, are filled with alluvium. The emplacement well was located approximately at 38° 38' N. Lat. and 116° 13' W. Long. (Nevada Coordinates are N1,414,340 ft and E628,921 ft, Central Zone). The well penetrated 732 m (2400 ft of alluvium, then passed through tuffaceous sediments and zeolitized tuff to 998 m (3275 ft) below the surface (F&S 1973).

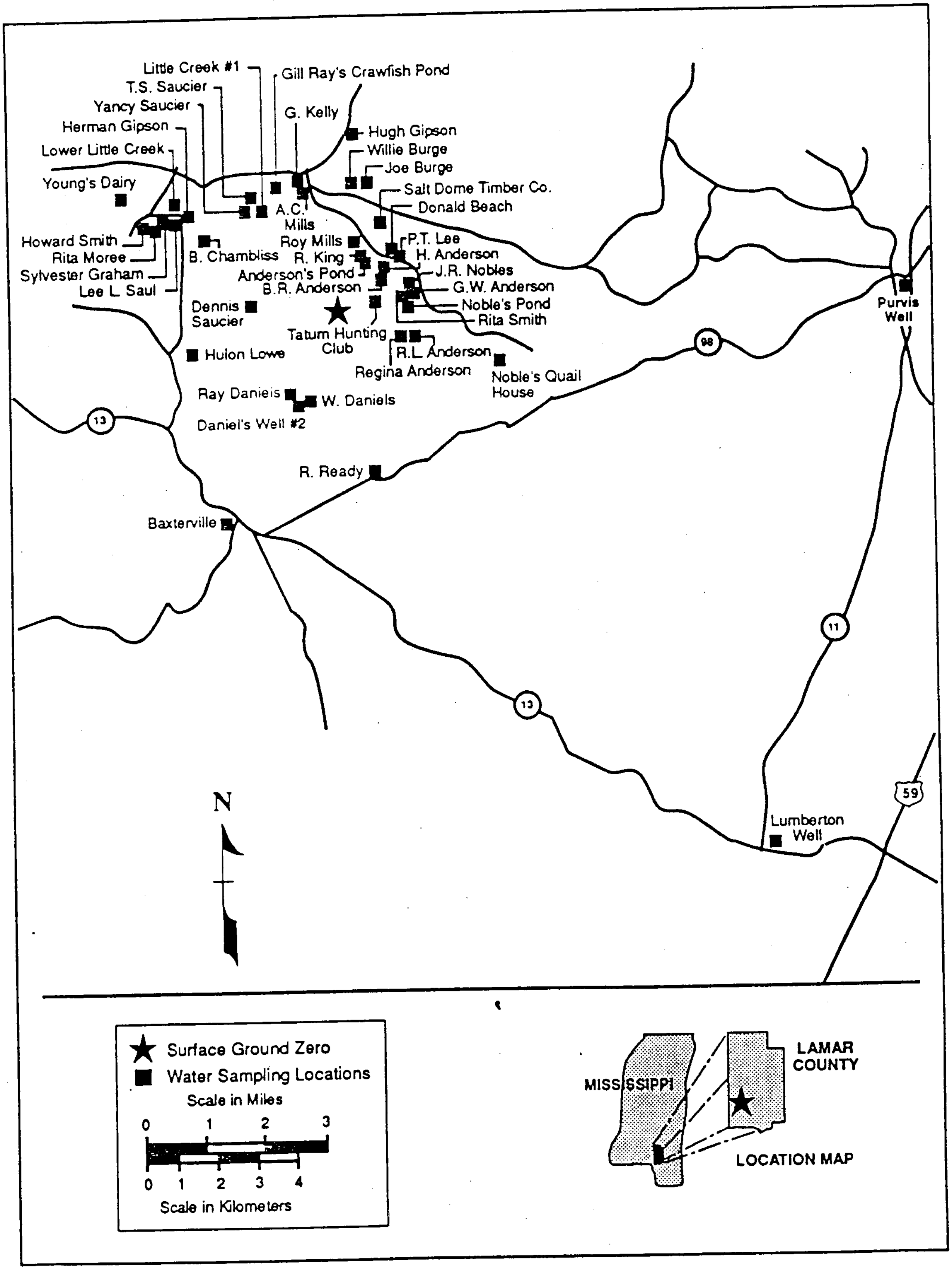

Exhibit 4-6-2 Map of Tatum Dome Sample Locations

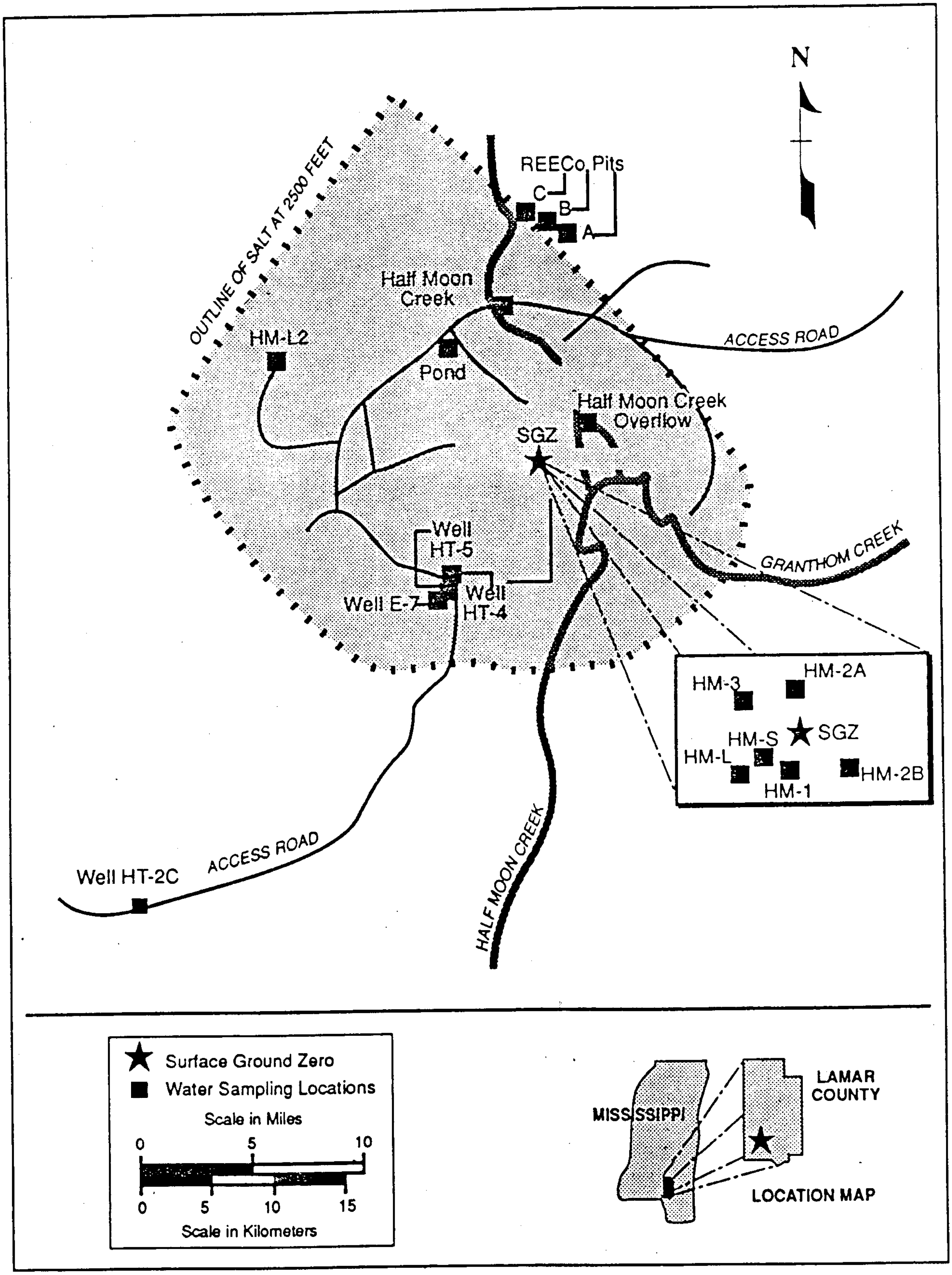

Exhibit 4-6-3 Hydrologic Monitoring Wells on Tatum Dome

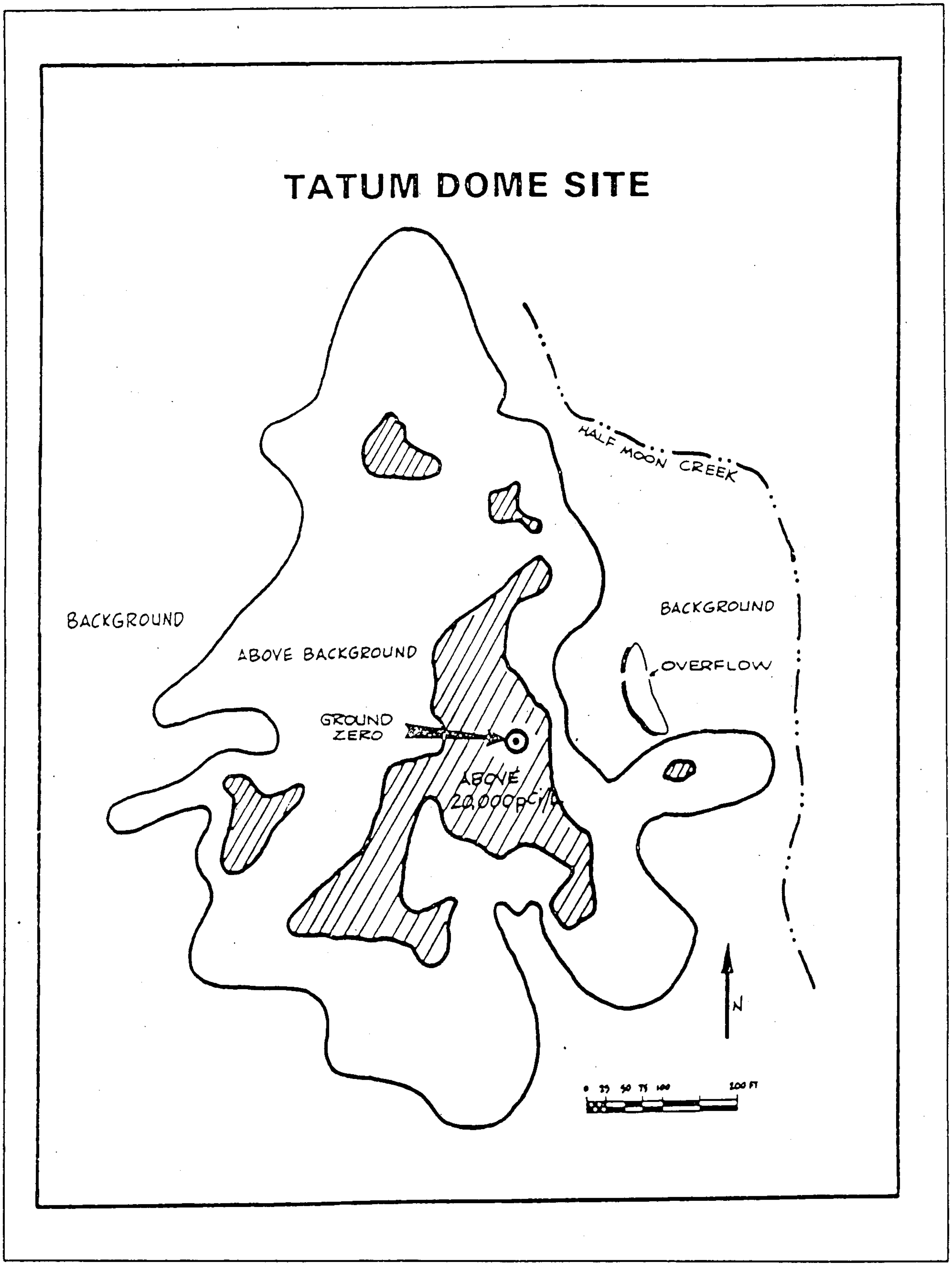

Exhibit 4-6-4 Contaminated Area Around Ground Zero at Tatum Dome

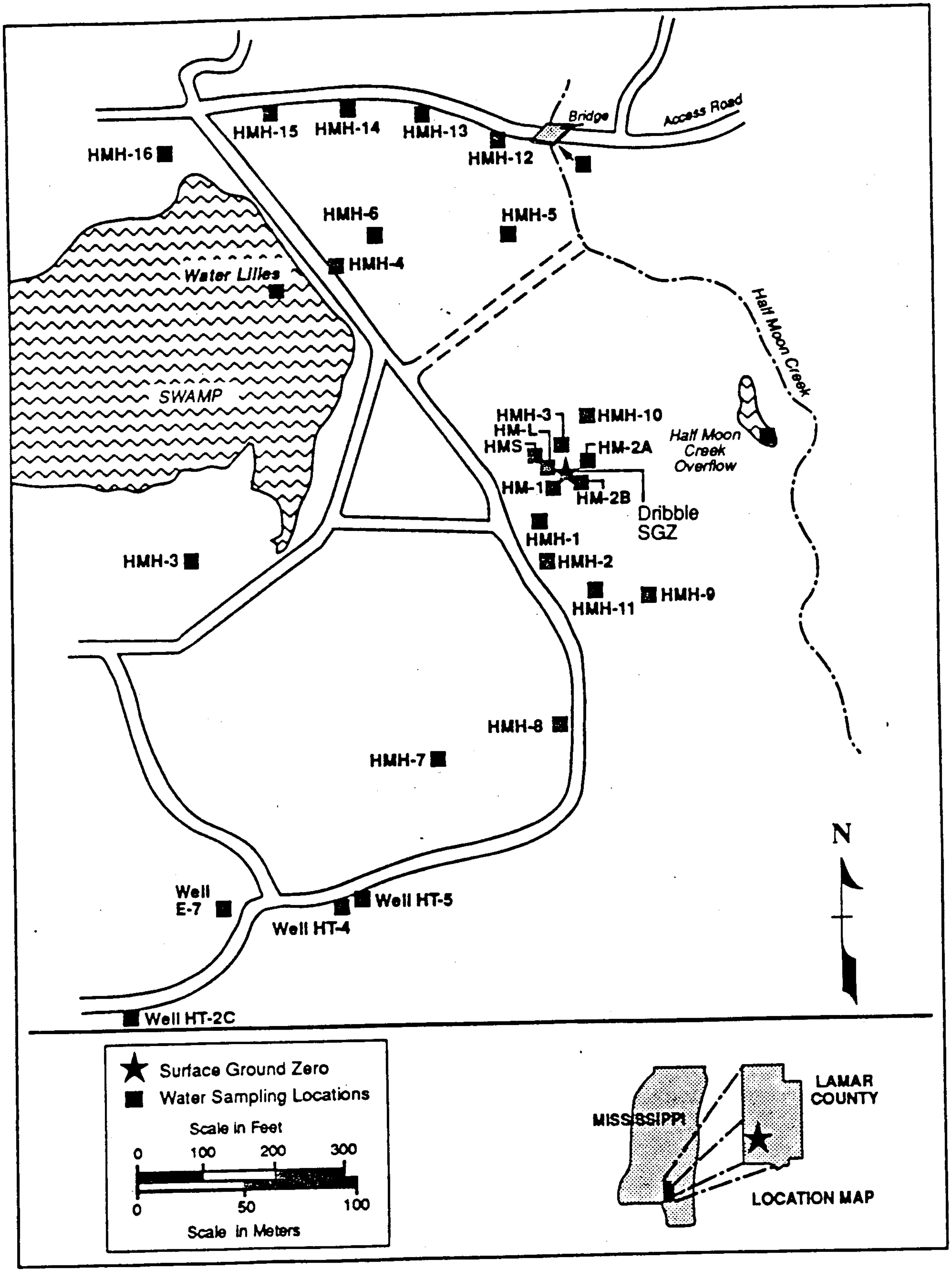

Exhibit 4-6-5 Hydrologic Monitoring Holes Near Ground Zero, Tatum Dome

4.7.2 Operational Activities

Project FAULTLESS was detonated at 1015 hours Pacific Standard Time on January 19, 1968, at a depth of 975 m (3200 ft) below ground surface in granite. FAULTLESS was an intermediate-yield event (200 to 1000 kt). It produced numerous fractures and faults over an irregular area having a diameter of about 1219 m (4000 ft). Most of the fractureswere associated with a subsidence bowl centered about 244 m (800 ft) south of surface ground zero. Minor rock falls occurred in the Tripp Veteran open pit mine near Ruth, Nevada. No radioactivity was vented at shot time, most of the radioactive material being entrapped in the cavity melt zone.

PHS conducted an offsite radiological monitoring program for this Project. Milk sampling stations at six sites and water sampling stations at seven locations were established for this event. To supplement the air sampling stations used for surveillance around the NTS, three additional stations were set up along with dose-rate recorders and TLD networks. No radioactivity above normal background levels was detected offsite by ground and aerial monitoring teams, by the gamma-rate recorders, or in any environmental samples (SWRHL 1969).

There is little doubt that the FAULTLESS event contaminated some groundwater. The static water level was 600 ft below ground surface while the detonation was hundreds of feet below that. The geologic materials penetrated were permeable enough to transmit large amounts of water into the zone containing the radioactivity produced by the event (Davis 1984). However, there were and are no effluents detected from this Project.

4.7.2.1 Criteria

Because of the depth underground that this test was conducted, it was predicted that radioactivity produced by the FAULTLESS event would be retained in the cavity melt or sorbed on rock surfaces with the exception of ^{3}H. Tritium in groundwater is not retarded by geologic media so it would be the first to move out of the FAULTLESS cavity. Since groundwater flow velocity is estimated to be only 7 cm/day (0.24 ft/day), it would take many years for any contaminated water to reach the nearest producing water well (USGS 1971). This flow estimate was made from groundwater gradients obtained from water elevations in widely-spaced wells. Inasmuch as the velocities are based on hydraulic conductivities averaged over a considerable thickness of aquifer, the real maximum velocity could be easily ten times as large. Given that no airborne radioactivity has ever been detected from this Project, the principal pathway for transport of radionuclides must be via groundwater, and groundwater monitoring is then the surveillance method of choice.

4.7.2.2 Surveillance System Design

The original hydrologic sampling network for FAULTLESS was established by the Hydrologic Program Advisory Group and published in June 1973 (AEC 1973). The original sampling sites are shown on Exhibit 4-7-1 and are listed in Table 4-7-1 together with other sites that have been sampled since the Program began.

Page II.7-B31 is missing from this document.

Table 4-7-1 Water Sources Sampled Annually at Project FAULTLESS

Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
Blue Jay, NV				
Bias Well	--	1977		Yes
Blue Jay Maint. Sta.	125	1972		Yes
Blue Jay Spring	Surface	1972	1976	Yes
Hot Creek Ranch	Surface	1972		Yes
Six Mile Well	112	1972		Yes
Well HTH-1	850	1972		Yes
Well HTH-2	604	1972		Yes

4.8 Project SHOAL, Nevada

Project SHOAL was sponsored by the Department of Defense and the U.S. Atomic Energy Commission as a part of the Vela Uniform Program. The purpose of the Vela Uniform Program was to improve understanding of the characteristics of seismic waves generated by underground nuclear explosions. This understanding was considered essential for verification of various treaty provisions. The objective of the Project SHOAL experiment was to determine the effects caused by detonation of a nuclear device in a seismically active area (AEC 1964).

4.8.1 Operational Area

The Project SHOAL site is located in the southwest half of Section 34, T16N, R32E, in west-central Nevada, about 45 km (28 mi) southeast of Fallon. It is situated on a 10-km^2 (4-mi^2) area of the Sand Springs Range in the Great Basin. This is a seismically active area with tremors and strong, shallow-focus earthquakes. About 200 quakes were recorded from 1945 to 1959. The nearest habitations are a ranch about 8 km (5 mi) west and Frenchman Station (consisting of a bar, restaurant, garage, and motel) located about 13 km (8 mi) northeast. An area map is shown in Exhibit 4-8-1.

The SHOAL surface ground zero was located on the northern portion of the Sand Spring Range in an area called Gote Flat. No permanent bodies of water or flowing streams exist and the major intermittent drainage course in the area leads to Fairview Valley. There is no gross surface manifestation of the detonation except for a minor subsidence of about 12 cm (5 in) to the northeast of surface ground zero.

4.8.2 Operational Activities

Project SHOAL was detonated at 1000 hours, PST, on October 26, 1963, at a depth of 369 m (1211 ft) below ground surface in granite. SHOAL had an estimated yield of 12 kt. No radioactivity was vented at shot time, most of the radioactive material being entrapped in the cavity melt zone. The test contaminated local groundwater in the vicinity of the detonation

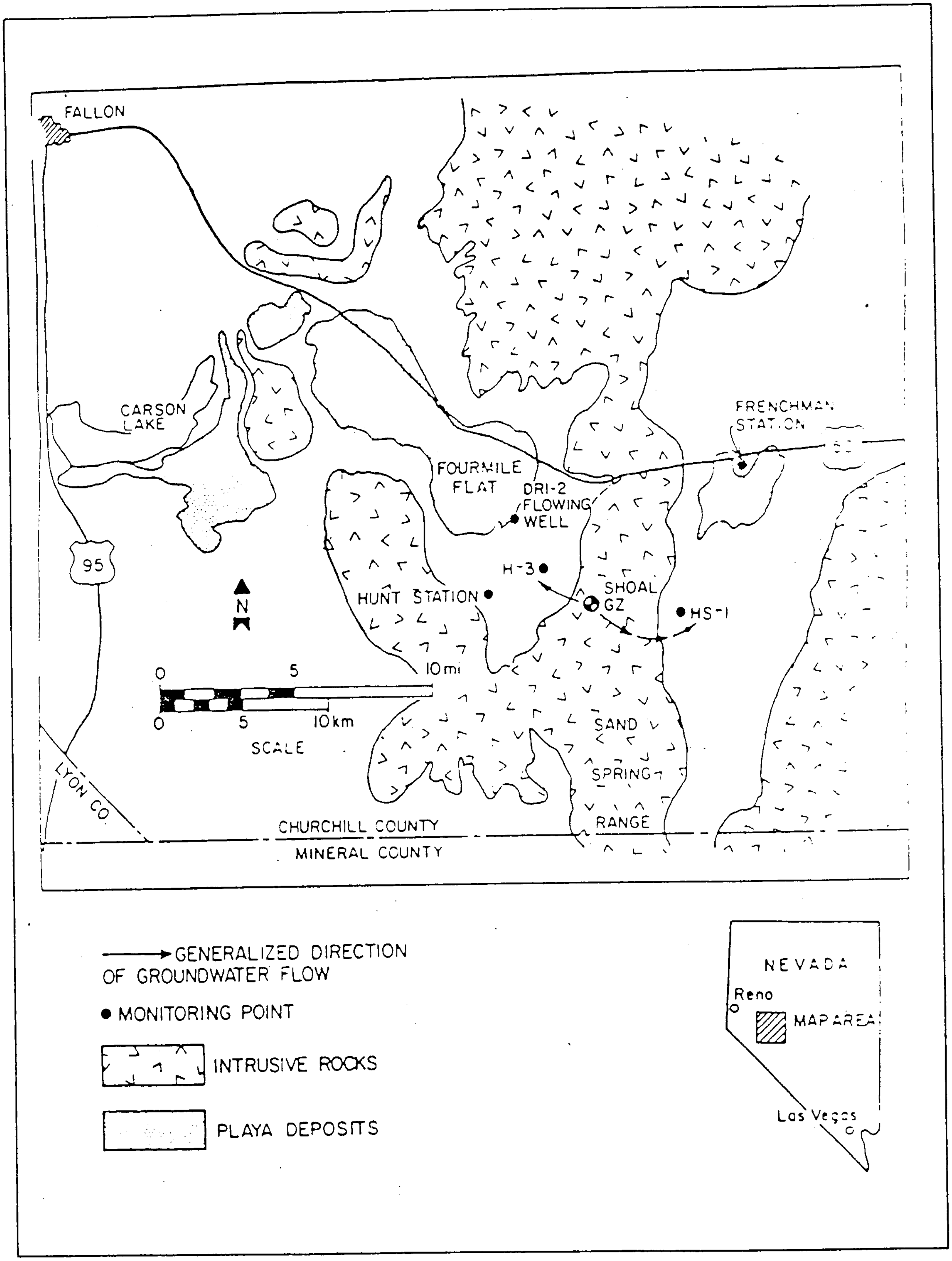

Exhibit 4-8-1 Project SHOAL Site and Initial Sampling Locations

because sufficient permeability exists in the host rock to conduct groundwater into the rubble zone. However, the rubble chimney does not extend to ground surface so that access to radioactivity would require drilling or reentry through the mine shaft, which is covered with a thick concrete slab. Small amounts of radioactivity were released during drillback but this was mostly gaseous and was channeled into filters and traps. Soil and cuttings contaminated with short-lived radioisotopes from post-shot drilling were mixed with clean soil and buried onsite.

Event day coverage as established by the PHS included 17 offsite mobile units and an aerial monitoring team. A milk and water monitoring network of about 20 stations was established prior to the event and maintained through 1964. No radiation leakage was detected from SHOAL and no increase in background radioactivity was observed in milk or water samples (SWRHL 1964).

The only effluents from this site occurred during the post-event drillback as summarized above. There are no known effluents at present.

4.8.3 Environmental Surveillance

4.8.3.1 Criteria

The Hazleton Nuclear Science Corporation of Palo Alto, California, conducted investigations and issued a report predicting that no radioactivity from Project SHOAL would leave the detonation area until the rubble chimney had filled with groundwater to near its pre-test level. This was predicted to take about 10 years. Although groundwater flow may be slow in this area, prudence suggests that monitoring to detect ^{3}H in groundwater at its earliest appearance is indicated.

The Hazleton Nuclear Science Corporation report additionally predicted that radioactivity produced by the SHOAL event would be retained in the cavity melt or sorbed on rock surfaces except for ^{3}H. Tritium in groundwater is not retarded by geologic media so it would be the first to move out of the SHOAL cavity. Given the levels of ^{3}H produced by SHOAL, it will take about 200 years to decay to a concentration of 1×10^{-5} µCi/mL, and even longer to reach the standard for drinking water. Since groundwater flow velocity is estimated to be only 0.04 to 0.46 m/year (0.15 to 1.5 ft/year), and since the nearest producing water well is 4600 m (15,000 ft) away, it will take 10,000 years or more to reach that well. There appears to be no hazard to local water supplies (DOE 1984).

Since only one permeable zone was encountered in all the drilling at the SHOAL site, this single zone could carry away all the groundwater recharge from the uplands at the site. Therefore, all of the recharge is concentrated in restricted zones and, after higher than normal recharge rates, groundwater may migrate much faster than assumed above (Davis 1984). Finally, since much of Nevada is seismically active, the possibility of natural disturbances occurring that may increase groundwater transport cannot be ignored. A groundwater monitoring program would permit detection of such transport changes.

4.8.3.2 Surveillance System Design

The original hydrologic sampling network for SHOAL was established by the Hydrologic Program Advisory Group at its meeting on December 12, 1971 and was based on the recommendations provided by Hazleton Nuclear Science Corporation and the Desert

Research Institute. The original sampling sites are shown on Exhibit 4-8-1 and are listed in Table 4-8-1 together with other sites that have been sampled since the Program began.

Table 4-8-1 Water Sources Sampled Annually at Project SHOAL

Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
Frenchman Station, NV				
Flowing Well	300	1972		Yes
Spring Windmill	--	1980		Yes
Smith/James Spring	--	1987		Yes
Frenchman Station	285	1972	1986	Yes
Hunt's Station	--	1972		Yes
Well H-3	375	1972		Yes
Well HS-1	400	1972		Yes

4.9 Project GASBUGGY, New Mexico

The objective of Project GASBUGGY was to determine the feasibility of stimulating the flow of natural gas in a low-permeability rock formation by use of a nuclear explosive. Project GASBUGGY was performed under a joint Industry/Government agreement.

4.9.1 Operational Area

The Project GASBUGGY site is located in the southwest quarter of Section 36, T29N, R4W, New Mexico Principal Meridian in Rio Arriba County, New Mexico. It is situated on the eastern side of the San Juan Basin. The nearest town is Farmington, NM, which is 89 km (55 mi) west of the site and had a population of 23,000 in 1967. The nearest community is Dulce, NM, which is 32 km (20 mi) east with a population of about 500. There were no habitations within 8 km (5 mi). The San Juan River is 32 km (20 mi) from the site at its nearest point and Navajo Dam (completed in 1963) is 37 km (23 mi) away. Of the land within a 16 km (10 mi) radius, 80% is in the Carson National Forest or in the Jicarilla Apache Indian Reservation. The permanent population within that radius was 149. There were six mining or tunneling operations at distances of 40 to 80 km (25 to 50 mi).

The surface ground zero for the test was 2200 m (7200 ft) above mean sea level at 36° 40' 40.4" N latitude and 107° 12' 30.3" W longitude. The emplacement hole was drilled into the Lewis Shale formation 1293 m (4240 ft) below the surface and 12 m (40 ft) below the gas-bearing sandstone.This location is on an El Paso Natural Gas Co. (EPNG) lease and is shown on Exhibit 4-9-1.

4.9.2 Operational Activities

GASBUGGY was detonated on December 10, 1967, at 1230 MST. The yield was about 29 kt, and the detonation created a cavity approximately 100 m (330 ft) high and 49 m (160 ft) in diameter. The PHS reported that its monitoring program detected no increase in radionuclides and no detectable tritium (^{3}H) in surface and subsurface waters offsite. No fission products were detected in air samples and ground monitoring and personal dosimeters showed no increase over background levels. Post-test isotopic concentrations in milk samples were similar to those in pre-test samples (SWRHL 1970).

During the production test phase in June and July of 1968, in which the effect of the detonation on gas flow was determined, about 1000 Ci of ^{3}H and 141 Ci of ^{85}Kr were released to the atmosphere. Although extensive monitoring similar to that mentioned above was conducted, only samples of atmospheric moisture showed any detectable test-related radioactivity, i.e., ^{3}H. The highest concentration detected was 1.2×10^{-9} µCi/mL in a sample collected on June 29 at 0.5 km (0.3 mi) from the release point. All releases were well documented and controlled, and no significant exposures to the general population occurred.

The only effluents from this site occurred during the production test phases as summarized above. There are no known effluents at present.

4.9.3 Environmental Surveillance

4.9.3.1 Criteria

The major aquifer is in the Ojo Alamo sandstone formation about 180 m (540 ft) above the test cavity. Although it is probably not suitable for drinking water or irrigation supply because of high total dissolved solids, prudence requires that groundwater monitoring be conducted to confirm that transport of radioactivity from the test cavity is not occurring.

Teledyne Isotopes' Palo Alto Laboratory prepared a groundwater contamination prediction based partly on data supplied by the USGS and suggested that, in the unlikely event the radioactivity reached the Ojo Alamo Sandstone, it would require many years to reach the discharge point of the aquifer in the San Juan River, about 38 km (23.5 mi) northwest of the site. Hydrology tests on the Ojo Alamo formation indicated a velocity away from the site of only 0.012 m (0.04 ft) per year so 5900 years would be required to reach the river. Biologically significant radionuclides such as ^{3}H, ^{90}Sr, and ^{137}Cs will have decayed to negligible concentrations in that time. This river supplies part of the drinking/irrigation water supply for communities downstream such as Blanco, Bloomington, Farmington, and Shiprock (DOE 1986, Teledyne 1971).

Activities that may lead to a release of radioactivity from the cavity include drilling for oil or gas nearby or a natural phenomenon such as an earthquake. Although monitoring of aquifers downgradient (i.e., to the west) may be all that is required logically, other water monitoring is conducted to allay public concern about use of nuclear devices.

4.9.3.2 Surveillance System Design

The original hydrologic sampling network for GASBUGGY was established by Teledyne Isotopes and the USGS in 1967 to provide pre-event and post-event comparison of radionuclide concentrations in surface and groundwater in the area surrounding the site (Teledyne 1971). The original sampling sites are shown on Exhibit 4-9-1 and are listed in Table 4-9-1 together with other sites that have been sampled since the Program began.

Table 4-9-1 Water Sources Sampled Annually at Project GASBUGGY

Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
Blanco, NM				
San Juan River	Surface	1973	1976	Yes
Dulce, NM				
City Well	Surface	1973	1976	Yes
Gobernador, NM				
Arnold Ranch	50	1972		Yes
Bixler Ranch	100	1972		Yes
Bubbling Spring	Surface	1972		Yes
Cave Spring	Surface	1972		Yes
Cedar Spring	Surface	1987		Yes
La Jara Creek	Surface	1972		Yes
La Jara Lake	Surface	1972	1976	Yes
Lower Burro Canyon	75	1972		Yes
Windmill #2	---		1974	Yes
Well 28.3.32.233 S.	60	1972	1978	Yes
Well 30.3.32.343 N.	70	1972	1973	Yes
EPNG Well 10-36	3600	1972		No
Jicarillo Well #1	---		1984	Yes
Spring Pond	Surface	1987		Yes

4.10 Project GNOME, New Mexico

The GNOME Project was the first nuclear explosive designed specifically for peaceful purposes and was the first underground event of the Plowshare Program to take place outside the NTS. The objectives of the Project were to investigate the phenomenology of nuclear explosions in salt, determine recoverability and producibility of isotopes, determine recoverability of heat, perform neutron physics experiments, and obtain information on device design (AEC 1973).

4.10.1 Operational Area

The Project GNOME site is approximately 40 km (25 mi) southeast of the town of Carlsbad in Eddy County, New Mexico. Carlsbad is a ranching and mining community located

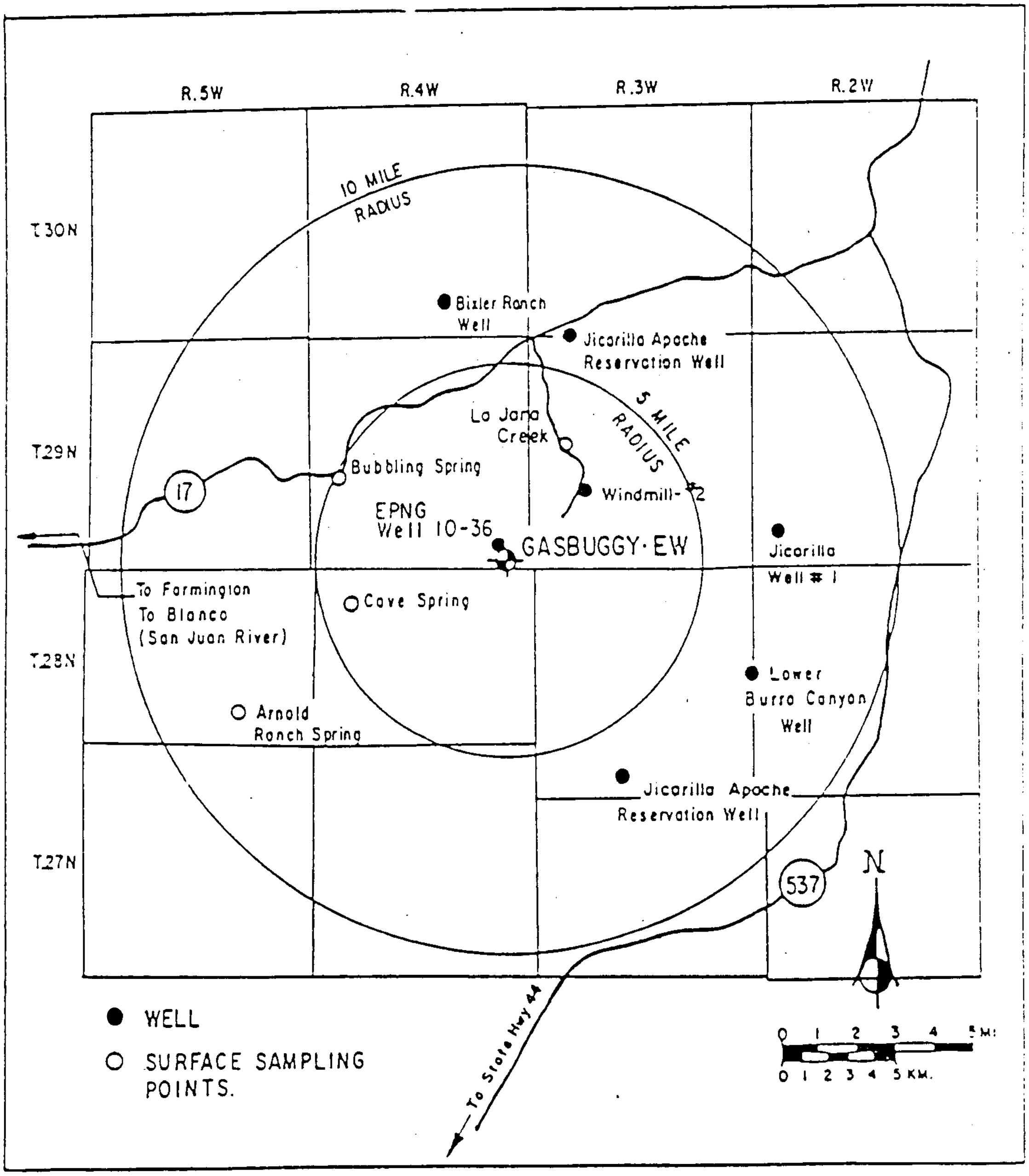

Exhibit 4-9-1 Project GASBUGGY Site and Initial Sampling Locations

approximately 48 km (30 mi) north of the Texas/New Mexico border. The site lies in the Pecos Valley and in the Great Plains physiographic province close to the Rocky Mountain province. The terrain is flat to gently rolling. The climate is semi-arid with a mean annual precipitation of 31 cm (12 in). Typical continental zone temperature fluctuations occur ranging from -24°F to 107°F (-31 C to 42 C).

The 640-acre emplacement site incorporated all of Section 34, Township 23S, Range 30E of the New Mexico Principal Meridian. The site control point occupied an additional 40 acres about 6.5 km (4 mi) north of the emplacement site in the northwest quarter of Section 10 in the same township. The working point for the device was 370 m below the surface at the end of a 340 m tunnel in the Salado Formation (rock salt). The only significant aquifer at this site is in the Culebra dolomite member of the Rustler formation about 200 m above the working point. This water is highly mineralized and is used only for watering livestock (DOE 1982). The location of the site and the water sampling locations are shown on Exhibit 4-10-1.

4.10.2 Operational Activities

The GNOME nuclear device was detonated on December 10, 1961, and had a yield of 3.1 kt. The venting which occurred soon after the explosion of the GNOME device, ejected material consisting of steam, dust, and gaseous radionuclides (primarily radioiodines and noble gases). The venting traveled down the drift (tunnel) and up the shaft that are shown on the section through the GNOME site in Exhibit 4-10-2. Aerial monitoring outlined the shape of the radioactive plume as shown in Exhibit 4-10-3 and ground monitoring by the PHS detected the footprint of the cloud on the ground. Because most of the release was gaseous, residual ground contamination was minimal. For example, the maximum gross beta detected on an air sample was 160 pCi/m^3 (1.6 x 10^{-10} μCi/Ml) and the maximum ^{133}I detected was 18 Pci/m^3 (1.8 x 10^{-11} μCi/mL) near the IMCC mining operations. Solid waste was created during the reentry mining to the GNOME cavity and liquid waste was created when the USGS conducted a tracer study in wells USGS-4 and -8. In this experiment, 10 Ci each of ^{90}Sr and ^{137}Cs, 20 Ci of ^{3}H, and 4 Ci of ^{131}I were injected into well USGS-8 and pumped from well USGS-4. After samples for analysis were taken from the USGS-4 water, the rest was reinjected into USGS-8 (DOE 1982).

Other sources of contamination at the site occurred during reentry and during preparations for a follow-on experiment named COACH that was subsequently abandoned. In 1968-69, radioactive materials that exceeded site cleanup criteria were collected and placed down the vertical shaft leading to the GNOME drift. With the exception of low-level contamination associated with the salt muck pile and the tracers used by the USGS, essentially all radioactive materials were confined to the detonation cavity, drifts, shaft, and drill holes. The criteria for cleanup became more stringent with time so that in 1977 it became necessary to remove and dispose of material with much lower levels of radioactivity. Cesium-137 was the primary isotope of concern and the low-level criterion required that much more material be involved in the cleanup than in the original effort. The contaminated materials were slurried in the GNOME cavity and drift and the incomplete COACH drift through holes DD-1 and LRL-7 respectively (DOE 1982).

Other than the samples removed annually for analysis, there are no effluents from the GNOME site so no effluent monitoring is conducted.

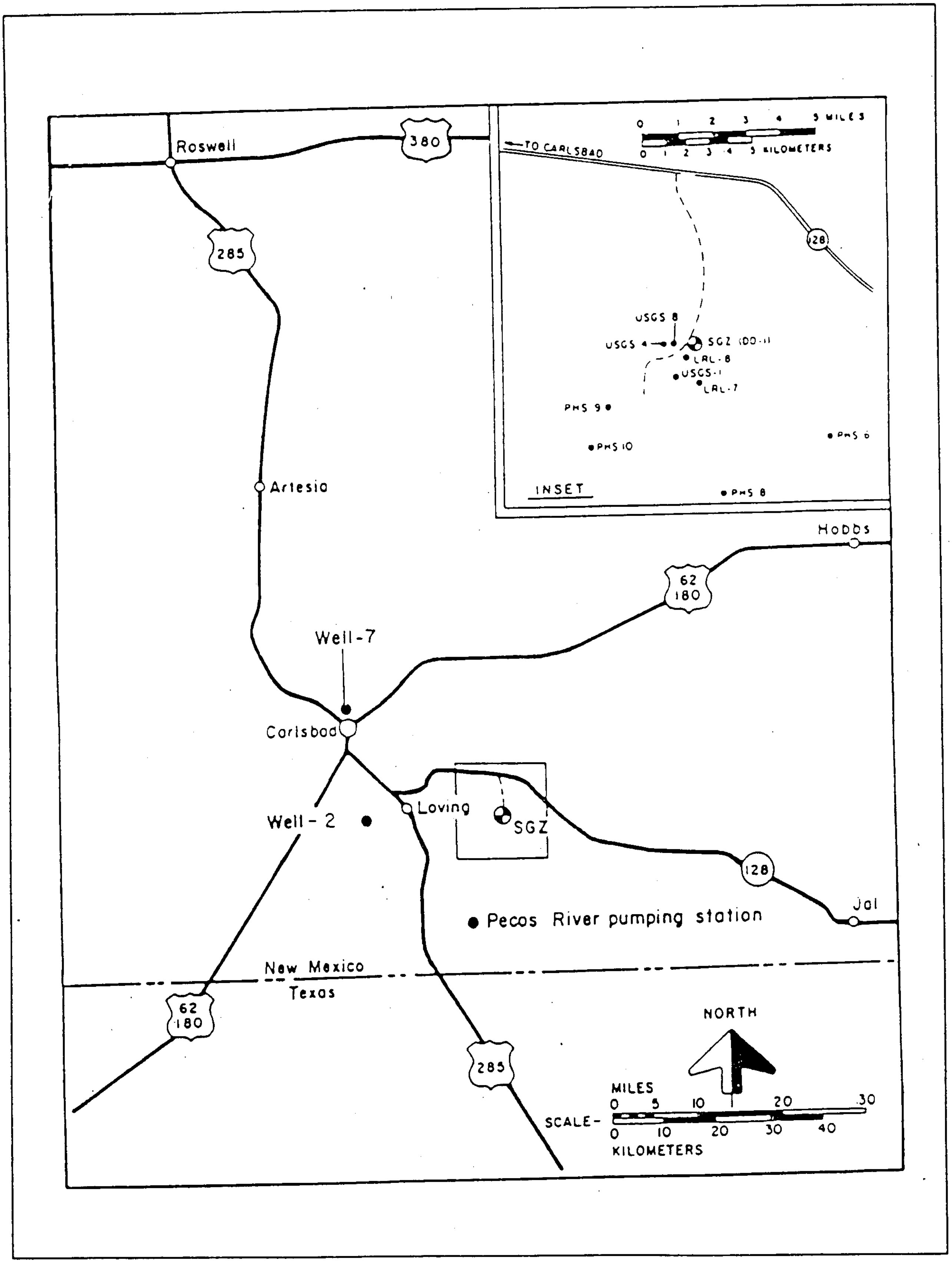

Exhibit 4-10-1 GNOME Site and Location of Water Sampling Points

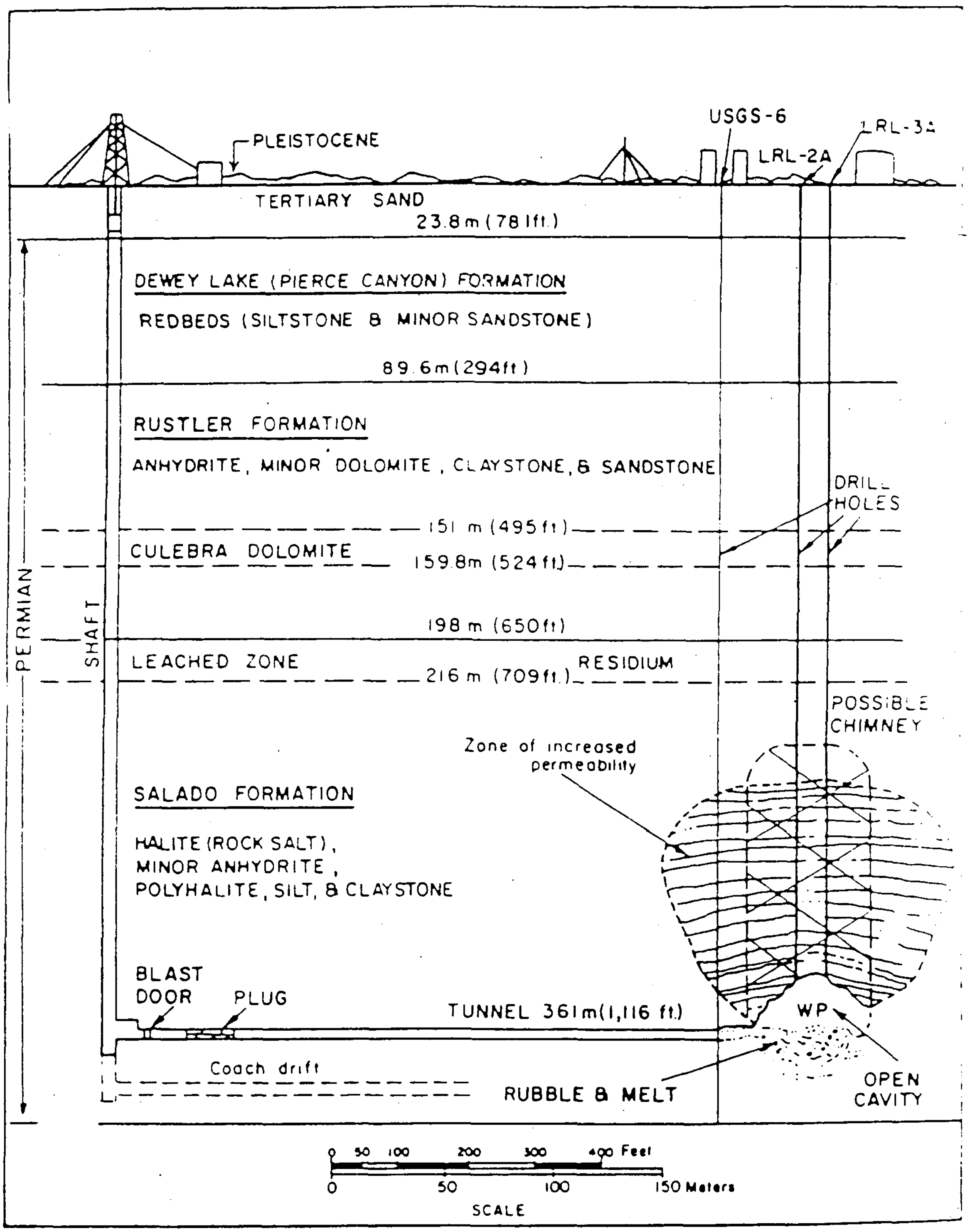

Exhibit 4-10-2 Section Through the GNOME Site

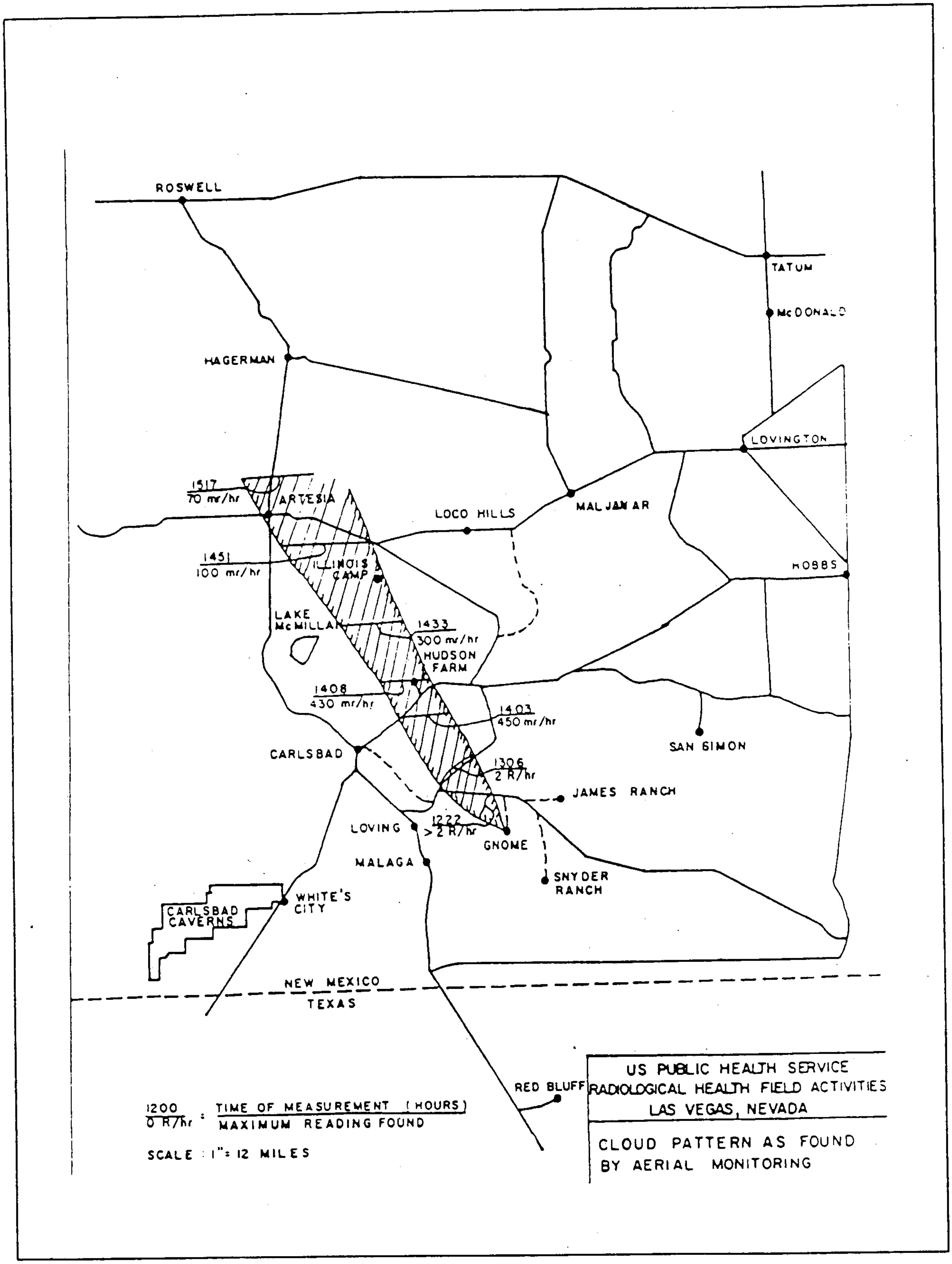

Exhibit 4-10-3 Radioactive Plume from Venting of the GNOME Explosion

4.10.3 Environmental Surveillance

4.10.3.1 Criteria

In the process of sinking the GNOME shaft, the rocks were inspected by USGS personnel. Water was not detected in the rocks above or below the Culebra Dolomite member of the Rustler Formation; therefore, the only aquifer in which transport of radionuclides could occur is in that dolomite member. Teledyne Isotopes, under contract to the U. S. Atomic Energy Commission (AEC), calculated the magnitude of the transport for this hypothetical case. All evidence indicated that no radioactive material was or could have been introduced into the Culebra Dolomite by the GNOME event. However, radioactive material was introduced into the Culebra by the USGS for the tracer experiment, and cleanup activities, including slurring operations, could have opened connections to the shaft/cavity material.

The Culebra Dolomite is about 152.5 m (500 ft) below land surface as shown on Exhibit 4-10-2. It is confined above by gypsum and anhydrite and below by clay beds. The artesian head causes the water to rise about 23 m (75 ft). The direction of water flow is westward at a rate of about 55 m (180 ft) per year and it is assumed that tritium from the test cavity would move at the same rate. At that rate it is assumed that decay and dilution would reduce the concentration in the water of the aquifer to below radiation concentration guide levels long before it becomes accessible at an existing use point. To insure that the calculations are correct, and because drinking water standards are so low, the groundwater pathway for human exposure must be monitored. The water sample collected in 1989 from well USGS-8 still had 1.3×10^{-4} µCi/mL or about 6.5 times the drinking water standard of 2×10^{-5} µCi/mL (40 CFR 141). The continued detection of radioactivity used in the USGS tracer study is another factor in requiring monitoring activities.

4.10.3.2 Environmental Monitoring

As GNOME was an underground test, and as the initial venting left no permanent residual activity on the ground surface, the required surveillance is limited to groundwater monitoring. Tritium is the radionuclide of concern for underground tests because it is not bound to the cavity melt nor sorbed on soil particles. It becomes part of the water molecule and will be the first radionuclide to move from the test cavity.

The original hydrologic sampling network for GNOME was established by the DOE/NV with assistance from DRI, USGS, and Teledyne Isotopes. There has been no change in the designation of the water sources to be sampled since they were established in 1972. The original water sampling locations are shown on Exhibit 4-10-1 and are listed in Table 4-10-1 together with other sites that have been sampled since the Program began.

Table 4-10-1 List of Water Sources Sampled at Project GNOME

Location	Sampling Depth (ft)	First Sampled	Last Sampled	Public Access
Carlsbad, NM				
City Well 7	432	1972		Yes
Loving, NM				
City Well 2	208	1972		
Malaga, NM				
City Water Supply	--	1972		Yes
Pecos River Station	180	1972		Yes
PHS Well 6	65	1972		Yes
PHS Well 8	480	1972		Yes
PHS Well 9	280	1972		Yes
PHS Well 10	330	1972		Yes
USGS Well 1	528	1972		Yes
USGS Well 4	486	1972		Yes
USGS Well 8	473	1972		Yes
Well DD-1	--	1981		No
Well LRL-7	745	1981		No

5.0 Analytical Procedures

For conventional tritium analysis, the sample is distilled and 4 mL are mixed with a scintillation cocktail and counted three times for 100 minutes each. If the tritium activity is less than 7×10^{-7} µCi/mL, then 200 mL of the distilled sample are electrolyzed to reduce the volume to <10 mL, of which 4 mL are mixed with the cocktail and again counted in the scintillation counter as above. This is an enrichment analysis and has an LLD of 10^{-8} µCi/mL. The 3.8-L (1-gal) sample is counted on an intrinsic germanium detector for 100 minutes without further treatment. A complete description of analytical procedures used by EMSL has been published in Report EMSL-LV-0539-17.

6.0 Quality Assurance and Quality Control

Quality assurance (QA) is an integral component of the LTHMP activities. In accordance with EPA policy and DOE requirements, the Quality Assurance Plan (1987) documents the quality assurance/quality control (QA/QC) program, including the organizational structure and personnel responsibilities, QC samples, and procedures for sample collection, handling, preservation, storage, analysis, and data validation. This section provides a brief overview of the QA program as implemented by EMSL-LV and documented in EPA/600/X-87/241 (1987).

Overall responsibility for all program aspects resides with the Division Director, Nuclear Radiation Assessment Division. The Division is composed of three branches; the respective Branch Chief is responsible for activities conducted within their branch. The Field Monitoring branch is responsible for station installation, instrument calibration and maintenance, sample collection and handling, and initiation of the data base. Samples are transferred to the Radioanalysis branch where unique sample numbers are assigned and analyses are conducted in accordance with standard protocols. Results are added to the data base. Additional responsibilities of the Radioanalysis branch include sample preservation and storage, instrument calibration and maintenance, sample archiving, and laboratory safety. Scientists in the Dose Assessment branch review, analyze, and interpret data and prepare reports, including the annual report. The Division QA Officer provides oversight, conducts internal audits, prepares or approves QA documentation, and ensures program compliance with the QA policy requirements of EPA and DOE.

All routine activities are documented in standard operating procedures (SOPs). These SOPs are prepared by the personnel performing the procedure and are approved by the QA Officer. The SOPs are periodically reviewed and updated as required. Numbered, controlled copies of SOPs are provided to all personnel in the Division. Adherence to the instructions contained in SOPs ensures consistency among operators and comparability of results.

Approximately ten percent of the work load in the radioanalysis laboratory consists of QA/QC samples. These include audit materials (standards), duplicate samples, matrix spike samples, QC check samples, and blanks; specific sample types employed are detailed in EPA/600/X-87/241 (1987). In some cases, the concentration or activity of the sample is known to the analyst (QC samples); these samples permit the analyst to monitor analytical performance and implement corrective actions, as needed. Quality assurance samples may be single or double blind; single blinds are known to be QA samples, but the concentration is unknown while with double blind samples, the analyst neither knows the concentration nor recognizes the sample as different from a routine sample. The QA/QC samples are used to monitor precision and accuracy of the analyses. Control charts are maintained of QA/QC sample results, as well as of calibration and blank (background) checks, to ensure the analytical system is in control.

Once analytical results have been entered into the data base and verified by the analyst, the data base is archived (controlled). All further changes require completion of a standard form and signature approval of the Dose Assessment Branch Chief. All data are reviewed by a media expert and a health physicist. Achieved precision and accuracy of analyses are calculated and compared to the DQOs. The DQOs are given in Section 4.2 of this document. Suspect values are flagged, investigated, and resolved. Standard statistical outlier tests may be used. Trending and other data analysis procedures are initiated only after the data have been examined and verified to be valid.

Training is another important aspect of the overall QA program. Personnel are initially hired based upon skills, education, and experience. On-the-job training in specific procedures is conducted using the mentor approach. New personnel work with senior experienced staff members, at first observing, then working with supervision, and finally moving to independent work. Single and double blind QA/QC samples are used to verify operator proficiency. Additional training is provided through seminars, formal training courses, and university classes.

Internal and external performance and systems audits are conducted routinely. The radiological laboratory participates in both EPA and DOE intercomparison studies. Standard materials are periodically submitted as double blind performance audit samples. Internal systems audits are conducted by the Division QA Officer. External audits are conducted by DOE and their contractors.

7.0 Data Management

Responsibility for initiating data management resides with the Chief, Field Monitoring Branch, EMSL-LV, including documenting sample collection and chain-of-custody procedures until the samples are released to the analytical laboratory. In the laboratory, the Sample Control technician, who is under the supervision of the Chief, Radioanalysis Branch, enters data from the sample collection forms into the Sample Tracking & Data Management System (STDMS), assigns a sample number, prepares the sample for analysis, and routes the sample to the appropriate station for analysis. Preliminary results of analysis are entered into a portion of the STDMS that is available only to analytical personnel. After the radiochemistry and/or spectroscopy supervisor verifies the data, it is then made available for general use.

Once the data have been verified and entered in the STDMS for general use, changes can be made only by the Data Base Administrator with the approval of the Chief, Dose Assessment Branch, EMSL-LV, who validates the reasons for changes.

8.0 Dose Estimation

The purpose of this surveillance is to insure that any leakage from the test cavity is detected as soon as possible in any groundwater aquifer that may be affected. If contamination of the groundwater by radioactivity from the test were to occur, dose estimation would be performed using the methods outlined in 40 CFR 141, National Primary Drinking Water Standards.

9.0 Reporting

Analytical results of samples collected at any of the LTHMP sites are reviewed as soon as available by a "media expert" to validate the results, i.e., to insure that they are consistent with historical records and to verify any anomalous results or require recounting or resampling as appropriate. The data are reviewed again when results from tritium enrichment are available. The final validated data are published in a formal annual report along with the other surveillance data generated during the calendar year. Confirmed anomalous results are discussed with the DOE/NV project officer or hydrologist. QA/QC data area also published in the annual report.

10.0 Document Control

Sample Control maintains files containing sample data cards, chain-of-custody records, and log-in sheets with sample numbers. All records for a given sample are linked by the sample number that is unique for each sample. The data and results are available in STDMS and can be tracked through the requisite annual reports. Sample collection data are maintained in logbooks in the Field Monitoring Branch.

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